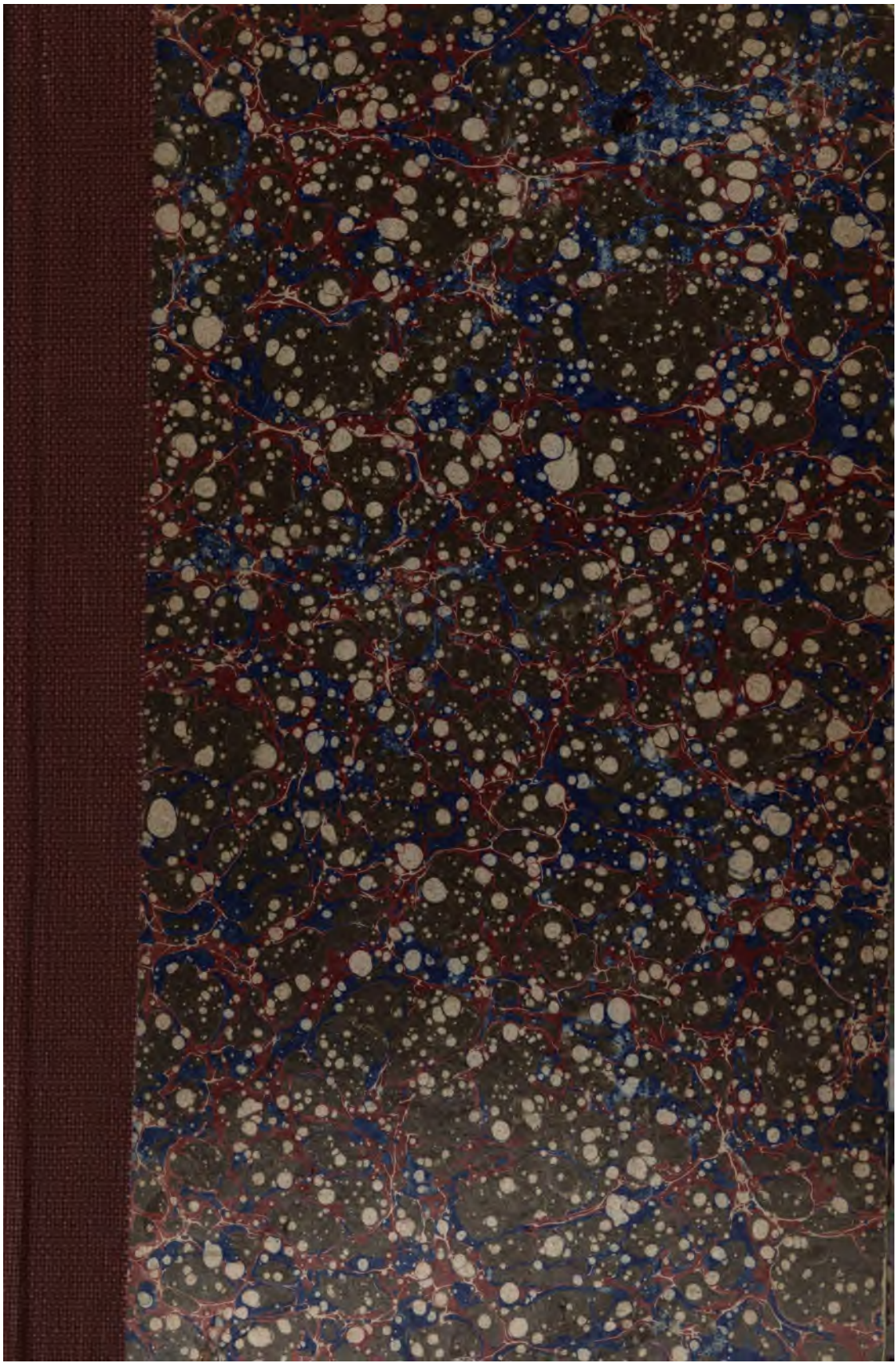

PRELIMINARY REPORT

OF

A GEOLOGICAL RECONNOISSANCE

OF

LOUISIANA.

BY

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GEOLOGICAL RECONNOISSANCE

OF

LOUISIANA.

As heretofore explained, the object of the exploration of western Louisiana, made by myself during parts of the months of May and June last, under the auspices of the Academy of Sciences and of the Board of Immigration, was a general reconnoissance of the geological and agricultural features of that portion of the State, rather than a detailed survey of any particular region. This I originally proposed to do single handed, and without any attempt at a systematic collection of specimens, upon the supposition that the geological map of Louisiana would prove to be essentially the reflected image of that of Mississippi, whereby the detailed examination of specimens would be rendered less necessary. Yet, while the presumption was proved substantially correct by the event, there are also points of diversity which, without the aid of a collection for comparison, it would have been exceedingly difficult to interpret correctly, since even with that advantage, it has been necessary to call into requisition the best efforts of chemical and microscopical analysis. Not only, therefore, has the pack mule proved a most important auxiliary to the success of the expedition, but its usefulness, as well as the quality and quantity of the work, has been signally enhanced by the intelligent and efficient assistance of my traveling companions. Especially am I indebted to our fellow-member, Dr. J. R. Walker, whose strong arm and cheerful spirit were always ready in time of need, while at the same time Mr. T. Scott Miller's administration of his onerous and patience-trying charge, has been worthy of all praise

With the route originally chosen, and the changes therein—rendered necessary by circumstances—the Academy is already ac-

quainted through the report of Dr. Walker. Its selection was base upon the presumed analogy of the geology of Mississippi and Louisiana, and preliminary information obtained from various source chief among which were the explorations of Judge Robertson, a data furnished by Messrs. Halliday and Coningsworth, of t Academy. Also valuable suggestions and data from Capt. G. W. Bayley, Gen. Blanchard, and others, of the city, and Judge Crawford, of Columbia, La.

The courtesy of the Opelousas Railroad, and Attakapas Transportation Company, in giving the party free transportation over the lines to New Iberia, effected a material saving of time, as well as of t somewhat scanty financial resources of the expedition. From Ne Iberia the party proceeded on horseback, at a rate averaging throug out the thirty days, between twenty and twenty-one miles per day ; distance which, in a diversified country, would have been too mu to allow of even a reconnoissance, but, under the circumstances, w advantageously exceeded, and even doubled in several instance where the uniformity of the country gave sufficient evidence of t sameness of formations and features already studied. It was th possible to devote more time to the examination of important loca ties, without risk of failing to reach the goal in time, or coming to co clusions based upon imperfect and hasty observation. Much valuab assistance was also received from courteous and hospitable gentl men on the route, to whom acknowledgements will be duly made the final report, which must await the completion of the chemic examination of the specimens.

THE PRAIRIES OF SOUTH LOUISIANA.

From the mouth of the Teche to Washington, on the Cocodrie, t west bank rises gradually and regularly, until above the latter poi it forms bluffs, elevated seventy to one hundred feet above ti water. As seen from the stream, therefore, the country appea hilly, and hence, probably, have arisen the popular names of "Co Gelee" and "Grand Coteau," which, to the observer traveling fro Iberia to Opelousas and Ville Platte, seem singularly inappropriat as he looks in vain for anything deserving the name on the level slightly rolling prairie plateau, which is highest near the edge the Mississippi bottom, and slopes in general to the SSW., as ind cated by the drainage of the country towards the Nezpique a

Mentau. In the southern and eastern portions of this region, too, the surface deposit of fertile, brown subsoil loam is thickest; the fertility of the country, on the whole, decreasing gradually as we advance northwestward from the Teche. The outcrops on the streams, as well as the phenomena observed in wells, show the entire prairie region to be underlaid by the strata equivalent to those of the Port Hudson bluff, where, down to a certain point, we likewise observe a decrease in the conditions of fertility of the materials from above downwards. As the surface of the formation was, doubtless, originally level in an east and west direction, it is probable that the white, ashy soils which prevail in the level pine woods and pine prairies of northwest St. Landry and north Calcasieu, are derived from the arid white and yellow siliceous silts and hardpans so prominent in the upper portion of the Port Hudson profile.* An inspection of this profile also suggests what is true for the greater part of the prairie region, viz: that while in shallow wells (15 to 35 feet, according to location,) good drinkable—though not very cold, and frequently limy—water may be obtained, wells of greater depth will strike fetid clays and bad water, unless sunk entirely below the Port Hudson strata. And, as will appear hereafter, artesian water can, doubtless, be obtained at moderate depths over the entire region.

Few sections of the United States, indeed, can offer such inducements to settlers as the prairie region between the Mississippi bottom, the Nezpique and Mentau. Healthier by far than the prairies of the Northwest, fanned by the sea breeze, well watered—the scarcity of wood rendered of less moment by the blandness of the climate and the extraordinary rapidity with which natural hedges can be grown for fences, while the exuberantly fertile soil produces both sugar cane and cotton in profusion, continuing to do so in many cases after seventy years exhaustive culture—well might the Teche region be styled by its enthusiastic inhabitants the "Garden of Louisiana." But a large part of this peculiarly agricultural region is now merely a range for herds of cattle, and in its northern portion, where intelligent culture is the more necessary, as the soil is less thrifty, a quarter or half bale of cotton per acre is oftentimes raised where an entire bale should be the minimum, if justice were done to the soil. The streams are usually bordered by fertile hom-

*See my paper on the "Geology of Lower Louisiana, and the rock salt deposit of Petite Anse," p. 3.

mocks, a quarter to a half mile wide, well timbered with lowland oaks, sweet gum, magnolia and poplar, *Liriodendron*, and more or less elevated above the stream, according to distance from the coast.

An undulating line laid through Ville Platte in a WSW. direction to the Calcasieu river, forms the northern limit of the prairie country; beyond, the Port Hudson strata overlaps older formations in undulating uplands, which, east of the Nezpique waters, are fertile and timbered, chiefly with oak and some short-leaved pine, but west of that stream form level and marshy, or slightly undulating long leaf pine woods, possessing a white siliceous soil, mingled with "black gravel, (bog iron ore,) of which numerous specimens are exposed to view by the labors of industrious crawfish—the only tillers of that soil at the present time. A similar soil, only whiter, prevails in the so-called "bay-galls"—marshy flats, overgrown with a dense thicket of "bay-galls," *Laurus carolinensis*, candleberry, and other shrubs—in which some of the smaller tributaries of the Nezpique and Calcasieu rivers take their rise.

The prairies of northeast Calcasieu are very level, often marshy, with a grey, ashy soil, and are dotted with clumps of long-leaved pine, while a low shrub, *Styrax pulverulenta*, covers densely the lower grounds. As we advance southward, black jack and post oak, mingling with the pine, testify of an improvement in the soil, on which innumerable herds of cattle and horses find luxuriant pasturage, while the houses of the pastoral population are dotted along the watercourses to the right and the left. These streams usually have their heads in low, marshy flats, but are often bordered by bodies of good, arable land, well timbered. In the more southerly portion, however, within forty or fifty miles of the coast, the clumps and strips of timber disappear altogether—the Calcasieu prairie proper being a treeless, perfectly level plain, whose soil improves to the southward, in consequence of the approach to the surface of a calcareous clay stratum, which is frequently exposed in washes. It is also struck in wells at the town of Lake Charles, occasionally with beds of marine shells, as is the case on the Mississippi coast.* On the shore of the lake, outcrops of reddish clay, sand and loam recall vividly the profile at Cote Blanche.†

Extensive cypress swamps border the lake and the Calcasieu river

*Report on the Geology and Agriculture of Mississippi.

†On the Geology of Lower Louisiana, *American Journal of Science*, Jan. 1869.

above ; numerous saw mills are engaged in cutting this timber, as well as that of the long-leaf pine, which borders the right bank, in lieu of the prairie on the left. No prairie, but only pine woods, which gradually become rolling as we advance northward, exists north of the west fork of Calcasieu, while south of the same, after traversing some pine forest, on the heads of Bayou Choupique, we find the prairies and marshy flats, with here and there a timbered island. On one of these islands are the petroleum springs which caused the sinking of the deep bore that has revealed so unexpected a mineral treasure.

THE OIL SPRING ISLAND.

The approach to the island is neither easy nor altogether pleasant. Full half a mile of deep, grassy bog has to be traversed, in which inexperienced horses and riders do some heavy floundering, and at the end of the journey the senses are greeted by an odorous breeze which, as one of the party graphically remarked, seems to blow directly from the lower regions. These are the effluvia of the principal well, spouting at the rate of sixty-five gallons per minute, a saturated solution of sulphuretted hydrogen in water, otherwise but slightly impregnated with mineral matter, but whose deadly effect, even upon vegetable life, is strikingly evidenced by the deadening of the marsh grasses for a considerable distance out. The deleterious influence does not seem, in any great degree, to extend to the general health of the workmen ; they sometimes get badly " choked " while working near the mouth of the well when there is no breeze, but rather like the general odor. Had the British medical expedition up the Niger ascended the Calcasieu instead, they might have had the satisfaction of seeing their test paper blackened to any extent ! Nor does the effluvium appear to interfere in any sensible degree with either the numbers, size, or appetite of the mosquitoes.

I will not discuss in this place the profile of the strata penetrated in this bore, which can be more fittingly done further on. There are several more petroleum and gas springs on the island and in the marsh, forming in several places a regular asphaltum pavement ; the gas is inflammable, and explodes violently when mixed with air and lighted ; it is evidently, in the main, marsh gas, or fire-damp—hydrid of methyl. But the gas now escaping from the deep well along with the water, seems to be chiefly sulphuretted hydrogen ;

the gas and water of the petroleum level having been tubed out, the present flow is essentially from the surface of the great sulphur bed.

There is also a "sour spring" on the island, which evolves a great deal of combustible gas but no petroleum; its water is acid and sweetish astringent, containing, in the main, sulphate of alumina, with gypsum and Epsom salt, and a little carbonate of iron. Considering the qualities of these waters, the island might be made a useful, albeit not a very pleasant, place of resort for patients.

PINE TIMBER.

The portion of Calcasieu parish lying west of the main Calcasieu river, and north of the west fork, together with the contiguous portions of St. Landry, Rapides, and the southern portion of Sabine, forms the main body of the long-leaf pine lands of the State, affording an immense supply of fine timber, while cultivation is restricted to the bottom and lower hillside lands. These, however, in the well watered region lying between the Little and the main Calcasieu, include some fine bodies of land, as in the Sugar Town region on the Ooskey, (usually called "Whisky,") Chitto, and Bundick's creek. The southern portion of this pine territory is level, sometimes marshy, and appears to be underlaid, as far north as the line of the prairies, by the Port Hudson strata. Beyond this line, however, they become more undulating, and sandy, sometimes gravelly, ridges announce a change of formation.

THE GRAND GULF GROUP.

On the waters of Nezpique, as well as on those of the Calcasieu, we here find in the beds of the streams outcrops of the materials characteristic of the Grand Gulf group of rocks, viz: hard, blue clay, ("soapstone,") or clayey sand, and soft sandstone ledges, void of fossils, and usually overlaid by the gravelly sands of the southern drift or orange sand epoch, whose ridges are capped by ledges of ferruginous sandstone. These ridges become very prominent in south Rapides, near the base line of the survey; and northward of Bayou Zoury, on the waters of bayous Anacoco and Taureau, outcrops of the Grand Gulf rocks become abundant and determine measurably the character of the surface. The soils, resulting from the decomposition of the hard clays, claystones, and "rotten sandstones" of this formation, are generally indifferent. But on the upper Anacoco, northward of Huddleston, we find the outcrops of

a stratum of gray, calcareous clay, which I have also observed on Sicily Island, at Grand Gulf, and on Pearl river, in Marion county, Mississippi.* It is this stratum which gives rise to the peculiar soils of the Anacoco prairie region. A deep black, very heavy soil, of a waxy touch, appearing on low ridges and at the foot of higher ones, and underlaid by the clay marl stratum itself as a subsoil. This soil is exceedingly fertile, as also the adjacent bottoms. It is, however, but rarely in large tracts; the largest, the Anacoco prairie proper, on Prairie creek, not exceeding about a thousand acres, while smaller patches occur, more or less, for some twenty miles to the eastward of the Anacoco. Pine uplands, with a heavy, red subsoil, whose greater or less fertility is indicated by a corresponding admixture of oaks, seem to be the prevailing feature of south Rapides, until the river bottom is approached.

As we advance towards the Taureau, the ridges become more abrupt and the outcrops of rotten sandstones on the hills more frequent—the usual symptom of the approach to the northern edge of the formation. The useful materials of the Grand Gulf series, besides the marl above mentioned, consist of building stones and clays; amongst these, a remarkably refractory fire clay occurring in south Caldwell and north Catahoula, now known as "chalk rock."

THE VICKSBURG GROUP.

Where the Alexandria and Sabine Town road crosses the Taureau, a change is obvious from the improvement of the soil, which bears, even on the ridges, a robust growth of upland oaks (prominent among which is the white oak,) with some short-leaved pine, while the bottoms are evidently profusely fertile. Small patches of prairie on the hills, with occasional outcrops of marl and fossiliferous limestone, show that we have reached the older tertiary, to-wit: the rocks of the Vicksburg group, underlying those of Grand Gulf. A stiff, red subsoil prevails here also; as, in fact, is the case over the greater portion of north Louisiana, from the predominance of clay formations underground.

In Mississippi and northeast Louisiana, the Vicksburg age is chiefly represented by alternating strata of highly fossiliferous marls and limestones. In west Louisiana, on the contrary, the marls are rather a subordinate feature, fossils are less abundant, and chiefly

*Mississipi Report, 1860.

such as pertain to a shallow sea; while the limestone containing them is usually interstratified with laminated clays, clayey sands, and lignite, and sometimes is altogether superseded by the latter materials, which are the products of deposition of shallow, brackish or fresh water marshes or lagoons. These features are strikingly illustrated by the interesting bluff at Sabine Town, Texas, as well as in those of the watercourses east and northeastward of that locality.

The territory underlaid by the Vicksburg rocks forms a band with nearly parallel sides, traversing the State in a WSW. direction, with a width of about thirty miles; intersecting Red river about Clourtierville on its southern, and Natchitoches on its northern border. The Casatche Hills, from coincident descriptions repeatedly given me, appear to consist of the Vicksburg rocks, capped by the ferruginous sands and sandstones of the southern drift or orange sand.

Good limestones for lime burning occur abundantly on the territory of this formation, its quality and quantity improving, on the whole, as we advance from the Sabine to the Washita; the same is true as regards the marls interstratified with the limestone ledges, which will be found especially efficacious in increasing the thriftiness of the heavy soils usually prevailing on this tract.

THE MANSFIELD GROUP.

A glance on the geological map of Mississippi, (of which that of Louisiana is thus far but the reflected image,) shows that northward of the narrow band of Vicksburg rocks which traverse the State, there runs parallel to it a broad belt of territory underlaid by the rocks of the Jackson tertiary. That the same formation exists in Louisiana, on the Washita, is proven by the discovery of its characteristic fossil, the huge Zeuglodon, at a point about halfway between Columbia and Monroe, as stated by the late Dr. Harlan, in 1832. I therefore expected to meet the same formation in northwest Louisiana, but was disappointed. The limited time at my disposal did not allow me to extend my own observations west of Red river beyond Mansfield; but from reliable data obtained from residents, I have little doubt that the same lignitic clay formation which underlies the entire region from the line of the Vicksburg group up to that point, extends as far north as Shreve-

port, and probably to the Arkansas line. East of Red river, the same formation continues unchanged in Bienville and Jackson, at least as far north as Sparta and Vernon ; nor have I any reason to believe that any essential change occurs farther north, within the State. It would thus seem that the Jackson strata are confined, in Louisiana, to the Washita region, while a large portion at least of the lignitic formation of north Louisiana evidently corresponds to the strata overlying the former, and underlying the marls and limestones at Vicksburg. In Mississippi these underlie but a small area ; but as their extensive development in Louisiana necessitates the adoption of a name, I propose to designate them as the " Mansfield Group," from the locality at which they are characteristically developed. The deep ravine which heads in the western portion of the town of Mansfield, exhibits all the varieties of gray or blue laminated clays and clayey sands which constitute the usual materials, but shows, in addition, a ledge of impure limestone, with numerous impressions of lignitized fragments of plants, which tends in a northwest direction, and is probably identical with that found near Shreveport. Numerous basin-shaped beds of lignite occur in this formation, some of which, from their easy accessibility to the navigation of Red river, will doubtless soon become of considerable practical importance, as the quality of the material is generally excellent.

IRON ORES.

Another important mineral, occurring chiefly on the Mansfield territory, is the concretionary brown iron ore, which pertains, properly speaking, to the orange sand deposits everywhere capping the lignitic strata. The latter being, in a great measure, impervious to water, the ferruginous solutions which were so extensively active during the orange sand epoch,* were kept stagnant and have, in many cases, formed very extensive deposits of a somewhat sandy, concretionary ironstone, containing from forty-five to sixty five per cent. of hydrated iron oxide. While these ores are none of the richest, their freedom from all injurious ingredients, such as sulphur and phosphorus, renders them specially adapted to the production of the finest qualities of wrought iron and steel ; their impurities being, in a great measure, only such as are requisite for the formation of a proper slag.

The best deposits of this ore which I have seen lie north of Pleasant Hill, in DeSoto parish, and in the salt lick region, on the

*See Mississippi Report, 1860.

Saline and Dugdemona, in south Bienville, where limestone is also convenient. Others are described by Judge Robertson as existing farther north. As these districts are, for the most part, densely timbered, these deposits will, doubtless, become of considerable importance whenever the means of communication shall be improved.

FACE OF THE COUNTRY.

With the exception of the level country bordering upon the lakes north of Red river, the territory of the Mansfield group is all undulating, oftentimes hilly, especially near the watercourses, and immediately south of Red river. The prevalent subsoil, as before stated, is a pretty stiff, red clay, derived from the underlying lignitic clays, and apparently of good native fertility, bearing a growth of upland oaks and, more or less, short-leaved pine. In north Natchitoches, south Bienville, and Winn, there is a considerable body of long-leaved pine on the Saline and Dugdemona, which is but partially interrupted on the territory of the Vicksburg rocks, continuing ENE. into Catahoula parish. As the long-leaved pine prefers a sandy soil, it frequently occupies the higher ridges only, where the orange sand predominates; while oaks, and short-leaved pine cover the slopes where the soil is stiffer and more productive, from the proximity of the underlying lignitic clay strata.

THE SALINES OF NORTH LOUISIANA.

Salt licks, not unfrequently with salt springs, occur sporadically scattered on the Mansfield territory north of Red river, chiefly on Saline and Dugdemona bayous, and on Lake Bisteneau. In most cases, limestone is found at or near these licks, and is always reached in digging or boring the salt wells. Sometimes the limestone occurs without the salt, either outcropping bodily or (as on the upper Dugdemona) indicated by black prairie spots. This limestone is mostly of a very peculiar character, consisting of horizontal layers of variously colored calcareous spar, so that on the vertical fracture it has a banded, marble like appearence; it is sometimes hard and solid, but more frequently crumbles easily under the hammer, somewhat like loaf sugar. This kind of limestone seems to be always void of fossils; but occasionally we find associated with it a rock closely resembling the "rotten limestone" of Mississippi and Alabama, which contains an abundance of shells. Having had access to this rock only in the piles of material dug from salt pits years before, at King's Salt Works on Bayou Castor, I was able

to find in it only the difficultly destructible shells of oysters. Amongst these were *exogyra costata* and *gryphaea pitcheri*, the leading shells of the cretaceous formation. And as in boring wells in these localities the limestone (?)* continued down to great depths, it is clear that we see in these cretaceous outliers the summits of ancient hills, around which the subsequent lignitic deposits gradually accumulated until (except in a few cases) the latter entirely covered even the hilltops. On the lower Saline bayou, however, as well as near Winfield, we find ridges of this peculiar banded limestone elevated fifty to ninety feet above the drainage of the country at the present time.

In mapping these saline outliers, from Cedar lick below Winfield to Lake Bisteneau, we find them trending in a NW. and SE. direction. A continuation of this line will strike, on the one hand, the main body of the cretaceous formation in Hempstead county, Arkansas, and Bowie county, Texas ; on the other, the isolated outcrop of banded limestone SW. of Chicotville, in St. Landry, and finally, the rock salt mass of Petite Anse.

It thus seems that a (now mostly subterraneous) cretaceous ridge forms the backbone, as it were, of Louisiana, continuing certainly to within seventy miles of the coast. It were premature in the absence of more positive testimony, to assert for the rock-salt of Petite Anse the same origin as that of the salines of north Louisiana, but with the facts before me, it seems to me most probable that such is the case. To the existence of this ridge must be ascribed the absence of the deep-sea Jackson strata, whose shells could not exist in a marsh and lagoon formation, such as produce lignitic deposits. In digging salt pits in north Louisiana, gypsum has repeatedly been found underlying the limestone, at a depth of eighteen to twenty-two feet ; when salt water was reached. At Rayburn's works in southeast Bienville, about two feet of compact granular gypsum, beautifully banded, were penetrated. The value of this material for agricultural purposes is too well known to need comment.

The crystaline limestone is in most cases very pure, sometimes chemically so, and will make the strongest possible lime. Much of the limestone near Drake's Salt Works on Saline bayou is of this character, and being readily accessible to navigation through Red

*So reported, but may have been gypsum in many cases.

river and Saline Lakes, with abundance of fuel at hand, there is no reason why the lime manufactured there should not replace the northern article in the markets of the lower Mississippi. Equally pure, but less convenient to communication, are the limestones near Winfield, and Chicotville.

As regards the production of salt, the extent to which the manufacture has been carried during the war, with very imperfect means, shows that north Louisiana might readily supply a large portion of the Southwest. The brines seem to vary from three to as much as eight to ten per cent. of salt, and the supply seems to be practically unlimited, at least at the larger licks, such as Rayburn's, Price's, and Drake's. At the latter, the brine is remarkably pure—almost free from gypsum; such at least is the case with the water of the deep (1011 feet) artesian well at that locality—one of eight bored there, without however, obtaining better brine than is gotten in pits, 18 to 24 feet deep.

I have not visited the salt works on Lake Bisteneau, but understand that the phenomena there coincide closely with those observed on Saline bayou. The salt produced there I analyzed during the war; it was almost chemically pure.

THE BORED WELLS OF CALCASIEU—PROFILE OF

KIRKMAN'S WELL.		W.—700 YARDS.—E.		LOUISIANA OIL CO.'S WELL.	
Thickness feet.	MATERIALS.	Format'n.	Thickness feet.	MATERIALS.	
354	Yellow clay above, with calcareous concretions. Then alternating strata of blue clay and sand; no trace of petroleum.	Port Hudson Group.	160	Yellow and blue clay, with some sand strata, soaked with petroleum.	
96	Sand, with flakes of clay. Sand, with coarse gravel. Sandy pipe clay.	Orange Sand Group.	173	Gray and yellow sand, with gravel, especially below. All soaked with petroleum.	
		Vicksburg Group.	10	Blue laminated clay, with a sandstone ledge.	
			40	Blue sandy limestone, in loose, rounded fragments rolling in. Stream of water with gas and petroleum.	
		Cretaceous Formation.	60	White, crystalline, crumbling limestone. Tube driven through.	
			100	Pure crystalline sulphur. Strong stream of sulphur water from surface.	
			147	Alternating strata of gypsum and sulphur, as above; about 35 feet of sulphur in all.	
			540	Gypsum—dense, granular, or coarsely crystalline, white or gray—very pure.	

The two bores named in the foregoing profile, are 700 yards apart east and west; Kirkman's well being also on an island in the marsh, on which, however, no petroleum springs existed.

THE QUATERNARY STRATA.

The most striking point at first sight, is the great difference in the respective thickness of the two quaternary groups, the Port Hudson and orange sand series. The latter had not been passed through in Kirkman's well below the depths at which in the other bore the great sulphur bed was struck. This must not be interpreted as showing that the latter is not horizontally continuous, but simply as a proof that before the deposition of the orange sand, the surface of the older formations was as deeply eroded here into hills and valleys, as is the case elsewhere, and that the surface of the orange sand itself had in its turn been denuded in a similar way, before the marsh, swamp and estuary deposits of the Port Hudson series began to be formed. To effect this, that surface now (454 feet below tide) must, of course, have been above the sea, level; and since in east Louisiana we find the later quaternary deposits as much as 450 feet above the present tide level, it is clear that a depression of at least 900 feet must have occurred after the drift period, followed by a re-elevation to about half that amount. The Gulf coast has therefore fully participated in the oscillations of level reported from more northerly latitudes, during the same epoch, and to a similar (minimum) extent; and the wide distribution of the southern stratified drift or orange sand, probably from the Susquehannah to the Colorado of Texas, and northwestward to the Llano Estacado, suggests the universality and close connection of the great events which produced it as well as the glacier drift of the North.

TERTIARY STRATA.

The quaternary strata, though soaked with petroleum, evidently bears no genetic relation to it. The blue, nodular limestone is manifestly the petroleum bearing formation, which, I have every reason to believe, identical with the Vicksburg tertiary, as exhibited at Sabine Town and elsewhere. The inconsiderable thickness of this formation, as well as the fact, already referred to, that it is denuded into valleys and ridges, one of which this bore happened to strike, renders it unlikely that the supply of oil will be found large or

lasting at any one point. It certainly has not appeared here in paying quantities, however great the rush of water and gas were at first. They are now tubed out.

CRETACEOUS STRATA.

The underlying white, crumbling limestone is not represented in any of the tertiary rocks underlying the Vicksburg series, but is undistinguishable from the rock of the saline cretaceous outliers in north Louisiana. Its close connection with the sulphur bed is evidenced by the fact that fragments of it have been brought up with sulphur regularly crystalized in its cavities. At the same time, we find the sulphur interstratified with gypsum, which, in its turn, is known to accompany the limestone of north Louisiana. The whole, therefore, belongs, doubtless, to one and the same age--the cretaceous--and the great gypsum bed at once suggests the connection with the great gypsum formation of the upper Red river and the Llano Estacado, which are known to possess a slight southeast dip.

THE SALT BED OF PETITE ANSE.

Knowing that the cretaceous formation underlies the coast of Calcasieu at a depth of about four hundred feet, and that a cretaceous ridge extends coastward as far as St. Landry, it requires but little stretch of imagination to suspect that the rocksalt mass of Petite Anse is but another cretaceous summit of that ridge. In that case, it is probable that the mass is of greater thickness than has yet been suspected, and that gypsum, and perhaps the sulphur bed, will be found beneath it.

As regards the latter deposit, its importance can hardly be overestimated, when we consider the primary importance of sulphuric acid to most modern manufactures. Its price regulates that of many of our every day necessities—its quality influences theirs. In view of the disadvantages under which the production of Sicilian sulphur labors, much impure pyrites is used in the production of sulphuric acid, seriously injuring the quality of the product. The Calcasieu sulphur is almost chemically pure; its supply is apparently unlimited. It will require considerable capital and the best of engineering skill to render the deposit available; but this once accomplished, its working cannot fail to be highly remunerative, the more, as its very gangue—gypsum—is itself an article of no mean value, so that nothing will be brought up from the shaft but marketable material.

I sincerely hope that the reconnoissance, whose results I have thus hastily sketched, will serve as an earnest and stimulus to the speedy organization of a thorough and detailed geological, agricultural, and topographical survey, such as the interests of the State imperatively demand. The effectual and speedy development of its resources require that these should be made known, from a source above suspicion, not only for the benefit of the actual inhabitants, but in order that capital and population may flow with confidence into its borders. Mere general declarations as to the advantages of the country cannot accomplish this ; the capitalist, the immigrant, want facts, with reliable and detailed information, before risking their fortunes. Louisiana, though one of the earliest colonies of the continent, is as yet one of the few States concerning whose aspect and resources no reliable information is generally accessible, and whose climatic and physical peculiarities are grossly misunderstood. The State owes its citizens the performance of a work which cannot be successfully carried out by private enterprise, or voluntary associated effort, such as originated the present expedition. The highest degree of competency, and best efforts of the gentlemen* now prosecuting the work during a few spare months of the year, cannot, within any reasonable period, accomplish the task, which the best interests of the State require should be done at once, and most thoroughly.

*Professors Hopkins and Lockett, of the State Seminary at Alexandria.

Prof. Chas. F. Hartt
with regards of
Eug. W. Hilgard

(2)

[From the American Journal of Science and Arts, Vol. XLVII, Jan., 1869.]

ON THE

GEOLOGY OF LOWER LOUISIANA

AND THE

ROCK SALT DEPOSIT OF PETITE ANSE.

By EUGENE W. HILGARD, Ph. D.,

of Oxford, Mississippi.

(ABSTRACT.)

The discovery in 1862, of a deposit of rock-salt on the coast of Louisiana, was a fact so unexpected to geologists, that at any other time a detailed investigation of its geological relations would quickly have followed the first announcement. The pressing necessities of the blockaded section soon caused its exploitation on the large scale, though in a very irregular manner; for a considerable period, these mines supplied the whole of the southwest. In November, 1865, Prof. Richard Owen made a brief examination of the locality, the results of which he published in the Transactions of the St. Louis Academy. A year

later Dr. Charles A. Gössmann, under the auspices of the American Bureau of Mines, made an examination of the locality, mainly with a view to the exploitation of the deposit; his report, published by the Bureau, as well as the specimens which he courteously exhibited to me, confirm previous conjectures that the overlying strata were the equivalents of the formation I have described as the "Orange Sand" of Mississippi. I therefore gladly availed myself at the earliest possible moment, of the offer of the Smithsonian Institution to defray my expenses in making a detailed geological investigation of the region. The low stage of water prevailing at the time (December, 1867,) rendered it possible to observe to the best advantage the formations exhibited on the banks of the Mississippi; the examination of which, from Vicksburg to the Passes, was a needful preliminary step to the determination of the formations of the coast.

Having previously examined and described the sections exhibited at Vicksburg, Grand Gulf and Fort Adams,* I merely landed at some intermediate points to verify the conclusion previously reached, viz., that below Vicksburg, no marine formation crops out on the river banks, reports to the contrary notwithstanding; and that the profiles at Natchez, Rodney and other points are essentially similar to that at Fort Adams, where we find the strata of the (fresh-water) "Grand Gulf group" in a position nearly or quite horizontal; overlaid, first by the materials of the "Orange Sand," which in its turn is capped by the stratum of the "Loess" or Bluff formation, covered by a thin deposit of "Yellow Loam."

Facing southward from the "Blockhouse hill" at Fort Adams, we observe a wilderness of the characteristic sharp ridges of the Loess region, often fore-shortened into veritable peaks, elevated between 300 and 400 feet above the river. In this region, the Grand Gulf strata have been traced southward by Dr. George Little, the present State geologist of Mississippi, as far as the head waters of Thompson's Creek, northwest of Clinton, La.

The Orange Sand proper is visible, near the river, as far south as Jackson, La., but farther inland extends to a lower latitude. As for the Loess, it appears in full force and characteristically developed for some distance south of Fort Adams. But (according to Dr. Little's observations) these features become gradually modified as we advance southward. The Loess deposit thins out, its materials become poorer in lime and fossils, and assume more and more the character of a common fine grained "hardpan;" the transition being by insensible de-

* See Report on the Geology and Agriculture of Miss., 1860.

grees, while the two extremes are very obviously distinct. At the same time, the clayey substrata which, farther above appear only in patches (as at Nevitt's bluff, two miles above Natchez, as well as at the latter place itself) are seen more frequently and continuously, until, at Port Hudson, they become predominant.

The exposure at Port Hudson, previously examined in part by Bartram, Carpenter and Lyell, is about three miles in extent, from the mouth of Sandy Creek above the town, to Fontania Landing, 1½ miles below. Its lower half is washed, and continually encroached upon, by the river; its upper portion is now inland of an extensive sandbar. The strata are disposed horizontally or basin fashion, and vary a good deal both in thickness and materials, as shown in the subjoined profiles, situated about a mile apart; the correspondence of strata is ascertained by actual tracing of the stratification lines.

Near Sawmill, Port Hudson.	No.	*Midway betw'n Port Hudson & Fontania.*
Yellow surface Loam. 4—6 ft.	6	Yellow Loam, sandy below; 8—10 ft.
Yellow Hardpan, 25 ft.	5	White and yellow hardpan, 18 ft. Orange and yellow sand, sometimes ferruginous sandstone, irregularly stratified, 8—15 ft.
Heavy greenish Clay, 7 ft.	4	Heavy, greenish or bluish Clay, 7 ft.
Gravel, sand and clay in irregular bands, like river alluvium; with pebbles, driftwood, leaves, and Mastodon bones, 6 ft.	3	White indurate silt or hardpan, 18 ft.
Heavy, greenish or bluish, massy clay, similar to No. 4; 25 ft. visible.	2	Heavy green clay, with porous calcareous concretions above, ferruginous ones below; some sticks and impressions of leaves, 30 ft.
	1	Brown muck, / White or blue clay, } with cypress stumps, 3–4ft.

At the stage of extreme low water prevailing at the time, the stump-stratum No. 1 was visible to the thickness of 10 ft. at its highest point; showing several generations of stumps above one another, also the remnants of many successive falls of leaves and overflows. The wood is in a good state of preservation; no prostrate trunks to be seen at present.

The main clay deposit, No. 2, varies but little in general character; although very solid, its tendency to cleave into prismatic forms renders it very liable to "cave" into the river. The upper portion of the stratum, especially near its southern end, contains strings of calcareous nodules, on stratification lines eight to twelve inches apart. No fossils save rare impressions of leaves.

No. 3 is exceedingly variable. At the northern end of the outcrop, it is a narrow band of swamp deposit; at the first of the profiles given, it bears the character of a sandbar; lower down, it returns to that of a swamp deposit; still below, it is represented by a fine white silt, without a trace of vegetable remains. Lower down again, a lignitic layer appears at its base, with leaves and fruit of living species of lowland trees; while near Fontania, it is again a sandbar, with an abundance of prostrate trunks of driftwood, coarse sand and pebbles.

The green clay stratum No. 4 varies little, either in thickness or composition, and like the stump-stratum No. 1, forms a convenient level of reference.

The hardpan stratum No. 5 I conceive to be the more immediate representative of the Loess proper, with which it is connected by gradual transition, though at times greatly resembling some of the materials of the Orange Sand. It is void of fossils.

The present profile differs in many respects from those given by previous observers, which lay some distance farther west, where the river now flows. The strata are accordingly as variable in an east and west, as in a north and south direction, and with the exception of Nos. 1 and 2, are such as are now shown in ditches cut into the modern river-bottom deposits.

The stump-stratum No. 1, however, as appears from numerous data collected by myself or contained in Humphreys and Abbot's Report on the Mississippi river, exists at about the same level (i. e., near that of tide-water) not only over all the so-called Delta-plain of the Mississippi, but also higher up, perhaps as far as Memphis, and all along the gulf coast, at least from Mobile on the east to the Sabine river. Wherever circumstances allow, the overlying clay stratum No. 2, is also observed. These facts indicate the wide spread prevalence, during the epoch succeeding the drift, of quiet, shallow fresh-water lagoons and swamps of slightly varying elevation; through which the continental waters may for some time have found an outlet without a definite channel representing the Mississippi of to-day. The Port Hudson profile appears to be typical, its features being reproduced wherever denudation has not removed these deposits down to the level of the stump-stratum, as is mostly the case.

The Five Islands.

The chain of five islands rising partly from the sea, partly from the coast marsh, between the mouth of the Atchafalaya and Vermilion river, have been described by Mr. Thomassy,*

* Géologie pratique de la Louisiane; New Orleans, 1860.

who attributes their origin to "hydrothermal" or "volcanic" action. His descriptions are sufficiently faithful to show the general resemblance of their geological structure; so that after visiting the three middle members of the chain, viz: Côte Blanche, Weeks's Island, and Petite Anse, I have thought it superfluous to extend my examination to the two extreme ones, viz: Belle Isle, the promontory west of Atchafalaya Bay, and Miller's Island (or "Orange Grove,") overlooking the plains of the Vermilion. These elevations lie nearly in a straight line bearing N.W. by W. from Belle Isle.

Côte Blanche.

The next in order, affords on its sea-face a fine exposure of the lower members of the Port Hudson profile. At tide-level, we have the blue clay with cypress stumps, the tops of which are often surrounded by alternate layers of clay, muck and sometimes lignite. The overlying strata consist, partly of blue clay similar to No. 2 at Port Hudson, partly of various colored loams alternating with the former; and exhibiting the same calcareous or ferrugino-calcareous concretions along the stratification lines. At a few points, these calcareous concretions resolve themselves into distinct fossils, representing the fresh-water genera *Paludina, Melania, Unio, Anodonta* and *Cyclas*, in an indifferent state of preservation. The entire visible profile is about 50 feet high; the highest point of the island rises as high as 180 feet, but in its interior no exposures exist, so that the higher members of the series are not verifiable.

Weeks's Island.

This island, lying 6 miles N.W. by W. from Côte Blanche, has an area slightly greater, viz., 2,300 acres; it is nearly circular; maximum elevation 160 feet above tide water. Unlike Côte Blanche, it is traversed by deep ravines which exhibit the geological structure. In the central and highest portion, these gullies are bordered by steep slopes composed of the most characteristic materials of the Orange Sand group. On the exterior slopes, however, we find in a position inclined away from the center of the island, the lower strata of the Port Hudson profile—green or blue clay with calcareous concretions, and imperfect fresh-water shells. The blue clay stratum with cypress stumps is met with in ditching, and is also known to exist in the beds of the neighboring bayous, as well as in the surrounding marsh.

Petite Anse, or Avery's Island.

Petite Anse lies about 12 miles N.W. by W. of Weeks's Island, and in its general structure much resembles the latter, to which it is slightly inferior in size, and about equal in elevation; its highest point, "Prospect Hill," on the north side, being 160 feet above tide-level.

An elevated ridge connects Prospect Hill with another high point near the southern slope of the island; and near the west end a ridge, on which Judge Avery's house stands, falls off steeply toward the Bayou Petite Anse. These three points inclose the valley in which the salt deposit has been found and which opens southeastward into the marsh.

The topography of the island, as well as the history of the mine, have been ably given by Dr. Chas. A. Gössmann of Syracuse, in a report of the American Bureau of Mines.* Up to the time of his visit, all the pits and shafts had been sunk through detrital strata, washed down from the adjoining hills, and frequently inclosing the vestiges of both animal and human visits to the spot. Mastodon, buffalo and other bones; Indian hatchets, arrrow-heads and rush baskets, but above all an astonishing quantity of pottery fragments, have been extracted from the pits. The pots doubtless subserved the purpose of salt-boiling; human handiwork has, however, been found so close to the surface of the salt, as to render it likely that its existence in mass was once known, before the time when, in 1862, Mr. D. H. Avery struck the salt itself at the bottom of a salt water well.

The surface of the salt undulates considerably, so that borings commenced at different levels have repeatedly struck salt at nearly the same relative depth, the absolute level of the rock-salt surface varying from 32 ft. below to 1¼ ft. above tide level. The salt stratum has itself been penetrated to the depth of 38 feet, without any perceptible variation in quality; its "floor" being as yet unknown. Dr. Gössmann's observations and specimens proved to his and my satisfaction, the existence of the Orange Sand on the Island; but its relation to the rock-salt, and the age of the latter, remained undetermined.

Since then, another shaft has been sunk by Mr. Chouteau of St. Louis, with the assistance of Mr. Dudley Avery, to whom I am indebted for a record of the strata penetrated. This shaft was located at a higher level than any previously sunk, on a hillside where, not far off, the Orange Sand crops out *in situ*. After passing through these strata, the rock-salt was struck again, at a level several feet higher than on any former occasion.

* On the rock-salt deposit of Petite Anse, New York, 1867.

There can therefore be no doubt that the salt deposit is older than the Orange Sand, which here as at Weeks's Island, forms the nucleus of the mass on whose outer slopes, as well as its higher points, the strata of the Port Hudson profile reappear characteristically; with calcareous nodules, fresh water shells and aquatic plants identical with living species. Not only is the reference level of the cypress stump stratum the same as elsewhere, but the green clay band, No. 4 of the Port Hudson profile, is also there.

The stratigraphical disposition of these deposits is quite remarkable. They conform not to the *strata*, but measurably to the *outline* of the Orange Sand nucleus, roughly following its slopes and curvatures. At first sight therefore it seems as though a local upheaval had taken place, and hence arose, probably, the reports attributing a volcanic origin to these elevations, whose isolated position in the level coast region would naturally give rise to speculation as to their mode of formation. Indeed the extent to which these strata are sometimes seen to dip, rather staggers the observer; but the upheaval hypothesis does not explain the facts, unless we are content to assume a separate effort of the sort for every hillock on the islands.

There can be no doubt that subsidence subsequent to deposition has been the cause of the extravagant dips observed sometimes. Where the Port Hudson series is more immediately superimposed upon the Orange Sand nucleus, the dips are moderate, and such as may well be assumed as resulting from deposition on inclined surfaces. But when we see an apparently undisturbed clay-stratum moving down hill like a glacier, so as to overflow a deposit of loose stones, we need not go far to find the cause of extensive dislocation and subsidence.

Belle Isle and Miller's Island.

All the data I have been able to collect concerning the structure of these exterior islands, tend to confirm the probable supposition that, like the three interior ones, they consist of denuded nuclei of Orange Sand materials, upon which the Port Hudson series was afterwards deposited.

It seems likely that the same is true of a low ridge called Côte gêlée, in Lafayette parish, bearing N. or N.N.E. Thomassy places in the same category the Grand Côteau des Opelousas and the Avoyelles prairie.

Age of the Salt Deposit.

The Orange Sand strata so rarely approach the coast, that the deposits underlying them in the Coast region have scarcely

been observed with certainty. Even the older strata underlying the blue stump clay have been observed at a few points only, viz: by the Delta Survey in the bed of the Mississippi river at Bonnet Carré and Carrollton, near New Orleans; at the latter city itself, in the boring of wells; at Salt Point, on Bayou Salé; and on the coast of Mississippi Sound.

The strata penetrated in the borings at New Orleans are considered by Sir Chas. Lyell as Delta deposits. But according to my examination, they are almost throughout demonstrably of marine origin, and while the species they contain are mostly (not all) now known to be living on the Gulf coast, yet the prevalence of species is very different from that now observed near the mouths of the Mississippi. In this respect, the fauna of these strata shows a great analogy to those described as Pliocene by Tuomey and Holmes, occurring on the Carolina coast.

It is most probable that the rock-salt of Petite Anse will be found when pierced, to be imbedded in the equivalents of the deposits penetrated at New Orleans and Bayou Salé, and of corresponding, probably early quaternary age, anterior to the drift or its southern representative, the Orange Sand.

Origin and extent of the salt deposit.

The absence of layers of the usual impurities of rock-salt, especially of gypsum, has induced Dr. Gössmann to suppose that it is not the result of the evaporation of sea-water, but owes its formation to crystallization from the purer brine of salt springs.

Our knowledge of the facts is still too limited to render a discussion of this point very profitable. In a very deep lagoon, withdrawn from the influx of the tides after the brine had acquired a considerable degree of concentration, all the gypsum might be found in a single bed at the bottom; upon it a large mass of pure salt, as in the present case; while the salts of the mother-waters would naturally have been washed away from the top. Or there might have been a succession of lagoons communicating with each only during high tides, and acting in a manner analogous to the process now practiced in salt-making on the sea-shore. The gypsum would then all have been deposited in the outer lagoons, while the inner ones would have acted as brine-pits, where pure salt alone could crystallize. Crystals of gypsum have repeatedly been found in shallow wells on the coast, beneath the "stump clay."

Upon any of the foregoing suppositions, calling into play a variety of circumstances not likely to be all simultaneously fulfilled, it does not seem probable that the rock-salt mass is

very extensive horizontally, or that such masses should occur frequently in the coast region.

A mass of salt 144 acres in extent and 38 feet thick is, however, a handsome specimen, even if these dimensions should represent maxima. The great difficulty in mining it, heretofore, has been the influx of water through the gravelly strata overlying. But it has most probably been attacked, thus far, at its lowest surface level. Wherever elsewhere the Orange Sand formation prevails, it rests on a deeply denuded surface; and "hills within hills" are of very common occurrence. From the data thus far obtained it appears that the same is the case with the rock-salt mass, and that its surface roughly conforms to the hills and valleys now existing. Workings should be begun at higher levels; and it would not surprise me to learn that the auger had shown the mass to be accessible by level adits in lieu of shafts, on the hillsides. The interior of the solid mass once gained from a point secure from surface water, all difficulty would be at an end.

Geological History of the Lower Mississippi Valley.

It appears from the facts stated in the preceding pages, that after the termination of the epoch of that Eocene period, represented by the Vicksburg group of fossils, down to the Quaternary era, marine deposits ceased to be formed on the northern border of the basin now represented by the Gulf of Mexico.

I have acquired the certainty of the existence, over a large portion of northern Louisiana, of the "Grand Gulf" series of rocks. From specimens in the collection of the New Orleans Academy of Sciences, it appears that apart from the usual materials forming these beds in Mississippi, they assume in the Harrisonburg region the character of compact limestone, which in places is said to be fossiliferous, and would thus furnish the clue to the age of the Grand Gulf group, for which I have vainly sought in Mississippi. The problem is one of great interest, as it involves the question whether or not the Mexican gulf has, within comparatively modern times, been disconnected from the Atlantic ocean. The absence of the cauldron in which the Gulf Stream is concocted might have exerted climatic influences reaching beyond the American continent, and would explain many discrepancies between ancient and modern faunas on the shores of the Atlantic.

It appears that similar limestones, almost assuming the character of black marble, occur in St. Landry parish, near Opelousas. Whether the southern outline of the formation passes thence toward the Calcasieu region, where petroleum has been found, or whether it trends northwestward into the par-

ishes of Sabine and Natchitoches, where limestone and sandstone ridges also exist, is a question still open. In the latter case, this outline would conform to the general shore lines of the great cretaceous and tertiary Mediterranean.

In Mississippi, the Grand Gulf series is mostly overlaid by the Orange Sand, deposited on a deeply eroded surface, and bearing itself the evidence of its formation by fresh water in a state of violent flow.* The southern outline of the main body of the Orange Sand runs southward of Opelousas, toward the mouth of the Sabine, whence, according to reliable information, a broad band of shingle extends toward Harrisonburg, Catahoula parish. This belt represents, probably, the most westerly bayou of the great Orange Sand Delta; while, as heretofore stated, the most easterly one extends from the neighborhood of Cairo along the western shore of the Tennessee river, down the valley of the Warrior toward the coast of Alabama. The middle and main pebble-stream evidently follows in general the course of the Mississippi river; but leaving it at the point where that river suffers its remarkable deflection eastward, we find the remnants of its ancient "bar" in the chain of the "Fire Islands," which lie directly across the shortest line by which the Mississippi could reach the Gulf, and no doubt have had their share in causing this deflection.

Both the size of the pebbles carried by this middle bayou, and their character proving transportation from high northern latitudes, show it to have been the main channel during the Orange Sand epoch. It is not surprising, therefore, that in the direction of its course the Orange Sand formation should extend farther south than anywhere else. The pebble-beds are now overlaid by fine sandy materials, proving a diminished velocity, owing, doubtless, to a general depression, but greater at the north than at the south.

While the lateral bayous descending through Louisiana and Alabama were closed at the end of the Orange Sand epoch, it is evident that the central channel continued open; inasmuch as the next succeeding deposit, viz: the Loess, lies in a trough-shaped depression of the Orange Sand materials, the line of contact being always conformable and devoid of any trace of atmospheric denudation. The perfect peroxydation of the materials of the Orange Sand would seem, nevertheless, to point to a certain period of exposure to atmospheric agencies, caused by a temporary diminution of the influx of northern waters, through the cessation of subsidence, perhaps.

During this epoch of quiet might have begun the formation of those extensive swamp and lagoon deposits, the lower mem-

* Am. Jour. Science, May, 1866; Miss. Rep. 1860, p. 26 and ff.

bers of the Port Hudson series, whose floor stratum, with its superimposed generations of cypress stumps, indicate a slow secular subsidence. The velocity of the latter seems gradually to have increased until the growth of old trees became impossible, and finally, in stratum No. 3 of the Port Hudson profile, we again meet the evidences of currents moving sand, pebbles, and drift-wood.

Then follows the Loess proper, a deposit utterly devoid, in Mississippi and Louisiana, of any evidences of fluviatile action —a uniform silt even in profiles of 80 feet, with scarcely a vestige of stratification, and none but terrestrial fossils.

The precise circumstances under which such a deposit could be formed, are perhaps a little obscure. There must have been such a depression of the whole country as to transform the immediate valley of the Mississippi, as far as Keokuk, as well as the valleys of the larger tributaries, into estuaries of the Gulf of Mexico, containing a mass of water too great to be sensibly affected by the variations now causing the annual overflows of those rivers (for otherwise the deposits must have shown lines of deposition), yet possessing a gentle flow above (since the materials of the bluff formation of Missouri and Indiana exhibit signs of fluviatile action); quite fresh in its upper portions (where fluviatile shells are found), but rendered unfit for the life of either a fresh or salt-water fauna by an admixture of sea-water, in its lower and almost stagnant portion, at tide level; and deriving its vestiges of animal life only from the "offscourings" of the adjoining unsubmerged lands.

Sir Chas. Lyell* inclines to consider the Loess as the product of "successive inundations of a great river," the absence of stratification from such deposits having, apparently, an analogue in the alluvial deposits of the Nile. But the case is far from being analogous; for the same phenomena are still observed in the modern deposits of the Nile, and are clearly attributable to the peculiarities of the hydrographic basin of that river; whereas, in the modern alluvium of the Mississippi, it is exceedingly difficult to find a uniform stratum two feet in thickness. The Nile mud is each year derived from the same rivers of Abyssinia, and equalized by intermixture and subsidence during at least 1,500 miles of its course. On the Mississippi, on the contrary, the deposits of different annual inundations are readily distinguished by the inhabitants for years afterward, according as the Illinois, the Missouri, Ohio, Arkansas or Red river happen to have furnished the main influx. The absence of any such differences from the Loess can only be explained on the assumption that the mass of

* Principles of Geology, 10th edition, p. 464.

water filling the channels was too great to be sensibly affected by such causes, the more so as the continental surface was sensibly diminished in consequence of a depression which, as far south as Fort Adams, cannot have been less than 400 feet, and on the coast not less than 200, but more probably the same as farther above.

The existence of the elevations on the Louisiana coast, above described, renders it necessary to assume that at the end of the period of depression—the "Champlain epoch"—the entire delta-plain (so-called) west of the Mississippi was covered by the deposits of the Orange Sand and Port Hudson series to an equal height; and that during the succeeding "Terrace epoch" of elevation, the veritable Mississippi—*our* Mississippi—swept away these deposits in excavating its present valley. At first it might sweep over or through the pebble ridge, but would finally turn to the direction of least resistance, leaving the "Five Islands" high and dry.

It would thus seem that, unlike other large rivers of the world which have from the outset added to the land by bringing down the materials to form their alluvial plain, the Mississippi has first formed by denudation the plain which it was subsequently to cover with its alluvial deposits to a comparatively inconsiderable depth. The western and southern limits of this denuding action would seem to be marked by the Grand Côteau des Opelousas, the Côte Gêlée and the Five Islands; and the materials swept away from this area doubtless contributed largely to form the foundations of the truly alluvial plain extending south and southeastward of lakes Maurepas, Pontchartrain and Borgne.

It is obvious how futile must be all attempts to estimate the age of the Mississippi river in absolute measure, by a comparison of the advance of its present delta into the Gulf, with the distance of its mouth from the divergence of bayous Plaquemine or Manchac. When the broad flood of the Terrace epoch contracted into the present Mississippi, that stream emptied into a sea rendered shallow by the deposition, within a comparatively short period, of a huge amount of material. Within such a sea its channel would be likely to change about, somewhat like those of the great rivers of China. *Now*, it is advancing into the deep water of the Gulf of Mexico, but at a very different rate, and by a very different process from that of simple alluvion. But the questions pertaining to this portion of the subject, together with the results of my observations in the Delta proper, I propose to discuss at a future time.

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SUPPLEMENTARY AND FINAL

REPORT

OF A

GEOLOGICAL RECONNOISSANCE

OF THE

STATE OF LOUISIANA,

MADE UNDER THE AUSPICES OF THE NEW ORLEANS ACADEMY OF SCIENCES, AND OF THE BUREAU OF IMMIGRATION OF THE STATE OF LOUISIANA, IN MAY AND JUNE, 1869.

BY EUG. W. HILGARD, PH. D.,

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SUPPLEMENTARY REPORT.

THE expedition of whose results the following pages contain the record and discussion, was, as will be remembered, equipped and carried out under the auspices of the New Orleans Academy of Sciences, its expenses being defrayed from funds provided, partly by subscription among the members of that body, partly by an appropriation made for the purpose by the Commissioners of Immigration of the State of Louisiana.

Its object was, primarily, to ascertain the general geological features of the State, thus gaining an insight into its probable mineral resources, also; and, at the same time, to make such observations concerning its topographical, agricultural and botanical features as time and opportunity permitted, and the publication of which would serve to make the advantages offered by the State to immigrants more generally known.

The *personnel* who volunteered for this service were, besides the writer: Dr. J. R. Walker, a fellow of the Academy, and Mr. F. Scott Miller, son of Dr. J. C. Miller, likewise a fellow of the Academy, all of New Orleans. All were well mounted, and a pack-mule was taken along, in charge of the junior member of the party, for the transportation of specimens collected on the route, at a distance from shipping points. A highly valuable suite of 250 specimens, representing all the salient features of the geology of Louisiana, was thus secured.

Unfortunately, the time at my disposal was, at the outset, unavoidably limited to about thirty days; but circumstances prolonged my absence from home to thirty-nine days, of which thirty were spent on the road (from New Orleans to Waterproof), five in preparations at the former city, and the rest going from and returning home.

During twenty-eight days actually spent in the saddle, the party traveled about six hundred and twenty-five miles, thus averaging over twenty-two miles a day. At this rate of progress, rendered necessary by the limited time within which a certain problem required to be solved, it was impossible to go far into details, to determine doubtful questions by lengthened research, or to go back upon observations too cursorily made at first. And single-handed it would have been impossible, within this brief space of time, to reach the results which enabled me, a few months later, to lay before the American Association for the Advancement of Science, at its Chicago meeting, the first geological map of Louisiana; the details of which have, of course, received numerous corrections by the subsequent investigations of my esteemed friend Professor Hopkins, without, however, changing in

any material points its general features. For this measure of success great credit is due the ready and intelligent co-operation of my companions, involving, at times, a very serious sacrifice of physical comfort, and perseverance under adverse circumstances. To Dr. Walker, especially, I am greatly indebted in this respect.

The geological and topographical survey of the State, under the auspices of the University of Louisiana, having been actively begun almost simultaneously, and carried forward ever since by Professors Hopkins and Lockett, more at leisure and with more ample means: I have thought it unnecessary to record here much information of a general character, that has already found a more extensive and profitable discussion in the reports made by these gentlemen. The detailed itinerary and narrative is also omitted, both as being of minor interest at this time, and as having already received some publicty from the pen of Dr. Walker, as well as in my preliminary report. I have also thought it best to omit such theoretical discussions of geological questions as have received a sufficient consideration in my prior publications, to which I refer those readers who may be desirous of obtaining fuller and more detailed information and discussion.*

For the chemical work which has so materially contributed to the interest and elucidation of the results, I am indebted to Mr. R. H. Loughridge, the assistant in the chemical department of the University of Mississippi, now Assistant State Geologist—the work having been performed at a merely nominal compensation.

While regretting the delay in the elaboration of this report, which has been caused by the accumulation upon my hands of the material of prior investigations, in consequence of the numerous pressing demands upon my time, of other professional duties: I trust that it may still be of undiminished interest, as the faithful record, and discussion by the light of later investigations, of the researches rendered possible and fruitful, by the earnest efforts and liberal support of this Academy.

THE ATTAKAPAS PRAIRIES.

The prairies near New Iberia have pretty stiff, black soil, which appears to become more and more calcareous as the coast is approached.

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* See *Report on the Geology and Agriculture of Mississippi*, 1860. *On the Quarternary Formations of Mississippi*, American Journal of Science, May 1866. *On the Tertiary Formations of Mississippi and Alabama*, ibid., January, 1867. *On the Geology of Lower Louisiana and the Rock Salt Deposit of Petite Anse*, ibid., January, 1869; final Memoir on same, Smithsonian Contr. to Science, No. 248, June, 1872. *Preliminary Report of a Geological Reconnoissance of Louisiana*, DeBow's Review, September, 1860; American Journal of Science, November, 1869. *Report on the Geological Age of the Mississippi Delta* (examination of the shells brought up from the Artesian well bored at New Orleans in 1856.) Report of U. S. Engineer Department, 1870. *On the Geology of the Delta, and the Mud Lumps of the Passes of the Mississippi*, American Journal of Science, Vol. 1, 1871. *On the Geological History of the Gulf of Mexico*, ibid., December, 1871. *On some points in the Geology of the Southwest*, ibid., November, 1872.

See also the reports of the Geological and Topographical Survey of Louisiana, by Professors Hopkins and Lockett, published in the reports of the Superintendent of the University of Louisiana.

Thus, in the prairies off Petite Anse and Grande Côte, or Weeks' Island, we commonly find underlying the usual twelve to fifteen inches of soil proper, a subsoil layer completely filled with "white gravel," *i. e.*, calcareous concretions from the size of a pea to that of a pigeon's egg. This layer, as seen in ditches, is from six to twelve inches thick; beneath it lies either a loamy silt, with spots of bog ore, or else a rather tough bluish clay, which forms the floor stratum of all the more southerly portion of the Attakapas prairies. South of New Iberia the latter are altogether treeless in their natural state, save here and there a honey locust on the low ground; the China tree and sycamore have, however, been largely planted near the homesteads, with a view both to shade and fuel. Within a few miles of the Tèche the surface is almost a dead level; so that after a heavy rain the water stands on the surface for some hours, seemingly at a loss as to the proper course to take for drainage. Gradually, however, it gathers into more or less definite shallow depressions (*marais*) and channels or "*coulées*" (as they are called by the Creoles), of which the bayou Cyprès Mort is a very characteristic example. Until within a few miles of the coast marshes, its course is defined only by a green band of reed-grass and cat tail, the water remaining, ordinarily, invisible, and its motion so slight that the duck-weeds (*Lemna*) and *Azolla* form a dense sheet of green, variegated with olive and red on its surface. It traverses, in its course, some of the most highly prized cane lands of this garden of Louisiana.

A specimen of virgin prairie soil, taken about midway between Petite Anse Island and New Iberia, gave the following results:

Depth, ten inches without change of color; below this depth it becomes more greyish, with an increasing amount of rounded, chiefly ferruginous concretions (or black pebble); gray loam at two to three feet; vegetation, grasses, mainly *Panicum* sp., and *Andropogon* (broom sedge), with *Vernonia* (iron weed).

Color, deep black; soil quite heavy; not as much so as the prairie soils of Mississippi and Alabama, but does not crumble on drying, like the latter.

Saturated with moisture at 12.8 degrees centrigrade, it lost 10.6 per cent. on drying at 204°. Dried at this temperature it consisted of:

Insoluble matter	67.21	77.17
Soluble silica	9.96	
Potash		.21
Soda		.17
Lime		1.74
Magnesia		1.48
Br. oxide of Manganese		0.27
Peroxide of Iron		2.78
Alumina		4.83
Phosphoric acid		0.21
Sulphuric acid		0.11
Carbonic acid		2.06
Water and organic matter		8.60
		99.63

The result of this analysis was most unexpected to me. The composition of this prairie soil differs widely from that of prairie soils of other States, in the small amount of both potash and alumina. Mississippi prairie soils yield from three to four times as much; the latter representing, approximately, the amount of clayey ingredient present. This shows a very large proportion of the soil's bulk to be made up of *fine* silex, to which rather than the clay present, its heaviness is owing. And as the clay is usually, in the Gulf States at least, the carrier of potash, the reason why the proportion of the latter is so small as to be even below the amount shown by the analysis of many pine wood's soils, becomes obvious.

How then, it may be asked, are we to account for the well established high fertility of this soil? The explanation lies, doubtless, in the large amounts of lime, phosphoric acid and organic matter present. The former vouches for the largely available condition of the potash, and assures us that the alumina dissolved in the analysis nearly represents the amount of clay in the soil. And it imparts to the soil that thriftiness which belongs only to soils capable of promptly converting all vegetable matter into true, black "humus."

As to phosphoric acid, one-quarter of one per cent., 0.250, is the maximum amount I have as yet found in the best soils of Mississippi, and this is rarely reached. The soil before us contains one-fifth of one per cent., therefore a very ample supply.

As to vegetable matter, the amount of chemically combined water belonging to the ferric oxide and clay cannot exceed two and one-half per cent. Of the 8.6 per cent. of "volatile matter," therefore, fully six per cent. are vegetable matter or humus; a very large amount for an upland soil. This, again, assures the thriftiness of the soil, by securing a large supply of ammonia, by rendering the soil highly retentive of moisture, absorbent of heat, and yet easy to till, and not liable to injury from drouth.

Yet the comparatively small percentage of potash warns us that continued culture in cane, without return to the soil, whereby potash is mainly drawn upon, will be sure, before long, to bring about exhaustion of the soil of its available potash, and consequent deterioration of the sugar crop.

The unnecessary withdrawal, annually, of almost the entire ash ingredients of the bagasse is, therefore, a very serious evil, to remedy which, consistently with the possible expenditure of labor at the critical time of the sugar harvest, is a problem well worthy the consideration of competent inventors.

It is interesting to compare with this prairie soil, and with the soils of the higher prairies of the Côte Gelée and Opelousas, that of the uplands on the islands. I have selected for this purpose the subsoil loam from Week's Island, taken on the southward (exterior) slope, some distance west from the lower dwelling house, where it forms a regular stratum some six feet thick. It is of a tawny brown tint, not very clayey. Saturated with moisture at 20.5° Cent., it lost at 204°, 8.96 per cent. of moisture, and consisted of:

Soluble matter	73.20	82.32
Soluble silica	9.12	
Potash		0.40
Soda		0.06
Lime		0.20
Magnesia		0.82
Br. oxide manganese		0.13
Peroxide of iron		4.76
Alumina		7.75
Phosphoric acid		0.11
Sulphuric acid		0.03
Volatile matter		4.02
		100.66

It will be seen that this loam differs in several material respects from the Iberia prairie soil, but the detailed discussion is best deferred to another place, in connection with the subsoils of the higher prairies.

The soil of the Cyprès Mort Woods, also profusely fertile, is of a lighter nature, contains a good deal more coarse sand, and is, doubtless, the result of the intermixture of the prairie soil with recent marine alluvion. It has not been analyzed as yet.

Approaching the Tèche, the prairie soil assumes a somewhat brownish tint, probably from the admixture of some of the red clay and loam, which form the bed and immediate valley of the Tèche, as they do of Vermilion and Red rivers

Northwestward of New Iberia, on the Vermilionville road, the black prairie continues, with apparently little change, for about twelve miles. The soil, as shown in road-side washes, is from twelve to eighteen inches in depth; then follows a yellowish subsoil, occasionally with some black (ferruginous) gravel, but not nearly as much of the calcareous kind, the liminess of the soil decreasing, apparently, as we proceed northward. Small woody strips along the coulées consist of Hackberry, Sycamore, Honey Locust, and near the bayou, of Live and other lowland Oaks. Wells in this region are mere pits, eight or ten feet deep, with bad water. Ponds furnish the supply for stock.

CÔTE GELÉE.

Beyond the point mentioned, begins the Côte Gelée country, with a slow, but decided ascent from the black prairie. Though still a prairie country, it is more rolling, with fewer ponds (*marais*) on its surface, and well defined channels for its water courses. On the slopes a brownish yellow or tawny subsoil loam crops out, often mixed with or underlaid by black gravel; the soil is not of as dark a tint, nor quite so deep, being on level ground about ten inches to the subsoil proper. An analysis of the latter is given below, alongside of that of the Opelousas prairie, with which it agrees very closely in composition.

Wells are eighteen to thirty feet deep, finding water not in sand, but in crevices in the gray or mottled loam,* mostly where the latter

*This loam, I conceive, to be the equivalent of stratum No. 5, of my Port Hudson profile, with which it is about on a level. See Am. Jour. Science, Jan. 1869; Smithsonian Contr. to Knowledge, No. 248.

touches blue clay or loam, which forms the bottom. The water is limy, not very cool, but drinkable, and probably not unhealthy.

The vegetation of the Côte Gelée prairies, like that of the Grand Côteau and Opelousas region, is remarkably little varied. Two or three species of *Paspalum*, with a sprinkling of *Andropogon* or broom sedge, dispute the ground with white clover. The Iron weed and Wild Indigo *(Baptisia)*, are the chief representatives of herbaceous growth, added to which is in most regions the *Helenium tenuifolium* or bitter weed, whose bright green, grass-like leaves often grievously disappoint the hungry beast of burden, and impart an intensely bitter taste to the milk of cows, feeding on it for want of something better.

From the prairie there is a sudden descent into the valley of Bayou Vermilion; on the slope we find the same dun-colored loam observed all along, underlaid by somewhat sandier material with black gravel. But the bed of the stream and its flood-plain are formed by quite a different material—a rather tough, red clay, evidently the congener of the Red River and Tèche deposits.

On its right (north) bank, the river is here bordered by a level wooded hommock, some thirty feet above the flood-plain, about a mile wide, and timbered with Water, Basket, Scarlet and Live Oak, Magnolia, Poplar (or Tulip tree), and much Sweet Gum; the soil lighter than that of the prairie, but excellent. The wells at Vermilionville are thirty to forty feet deep, good water being found in sand underlying the yellowish clay or loam.

THE OPELOUSAS PRAIRIES.

There is a very great sameness in the general features of the country from the Côte Gelée to Opelousas, and beyond to Ville Plate, where we reach the northern limit of the prairie region. Apart from the usual local differences resulting from diversity of level and position, the general change, as we advance northward, is a very gradual diminution of the depth, and intensity in the tint, of the prairie soil, showing a diminished amount of vegetable matter; while at the same time, the subsoil appears at the surface more frequently, the more as the country is more rolling, while *marais* and ponds become more scarce. Concurrently there is an obvious diminution of the thriftiness of the soil in its natural condition; although under high cultivation, (which unfortunately, it rarely receives,) it makes excellent crops both of corn and cotton.

About halfway between Opelousas and Ville Plate, on the plateau dividing the waters of Bayou Cocodrie from those of the Mentau, specimens of soil and subsoil were taken in the open prairie. I regret that the limited means at my command did not permit either of taking more abundant specimens of soils, or of having even all of those collected subjected to analysis. A single specimen analyzed cannot, with any degree of confidence, be considered as giving a fair insight into the general characteristics of the soils of an extensive region. The soils, however, are more variable than the subsoils; the latter being, in the case before us, a regular geological stratum of considerable uniformity

of character. From this the soils are derived by processes somewhat variable in kind and intensity; hence it seems fair to conclude that the examination of the subsoils is better adapted to convey information of a general character. For this reason I have, in most cases, preferred the latter in the present investigation.

The surface soil, at the point mentioned, was about twelve inches deep, of a grayish black tint, not very clayey. The vegetation, same as above stated in general.

The soil, saturated with moisture at 23.9° Cent., lost 5.42 per cent. at 204°. Dried, at this temperature, it consisted of:

Insoluble Matter	86.81	90.15
Soluble Silica	3.34	
Potash		0.19
Soda		0.14
Lime		0.15
Magnesia		0.23
Br. oxid Manganese		0.09
Sesquoixid of Iron		1.94
Alumina		2.09
Phosphoric acid		0.23
Sulphuric "		0.04
Water and organic matter		4.82
		100.07

The subsoil was taken at fifteen to eighteen inches depth; color, a tawny brown. Saturated with moisture at 21.4° Cent., it lost at 204°, 8.94 per cent. of water That of the Côte Gelée, taken near its southern extremity, on a hillside, of the same tint, saturated with moisture at 19.6° Cent., lost at 204°, 7.78 per cent. of water.

That of Grande Côte or Weeks' Islands, which I again place here for comparison, at 20.6, absorbed 8.97 per cent. of moisture. Their composition was found as follows:

	SUBSOIL LOAM.		
	Opelousas Prairie.	Côte Gelée.	Grande Côte.
Insoluble Matter	74.74	75.39	73.20
Soluble Silica	6.96 — 81.70	8.31 — 83.70	9.12 — 82.32
Potash	0.32	0.33	0.40
Soda	0.01	0.02	0.06
Lime	0.25	0.13	0.20
Magnesia	0.60	0.69	0.82
Br. Ox. Manganese	0.08	0.15	0.13
Peroxid of Iron	4.79	4.29	4.76
Alumina	7.72	6.48	7.75
Phosphoric Acid	0.15	0.16	0.11
Sulphuric "	0.01	0.05	0.03
Volatile Matter	4.36	4.54	4.02
	100.00	100.54	100.66

The most obvious difference between these materials and the prairie soil from Iberia, is the very small amount of lime, being over six times less than in the latter. Hence the comparative unthriftiness. The analysis of the surface soil also shows a slightly smaller amount of

potash, and very much less of vegetable mold. Doubtless the application of lime or plaster would result in a very great improvement. But for so close a soil, in which roots can descend to moderate depths only, the amount of potash is quite small—as, in fact, it seems to be in most Louisiana upland soils. The phosphates, likewise, are in smaller quantity, yet not deficient. As in the case of the Iberia soil, there is here a very great predominance of fine siliceous material over the clay; and assigning to the latter as well as to the ferric oxid, their usual quota of combined water, we have remaining but 3.65 per cent. for vegetable mold. Hence the slight capacity for absorbing and retaining moisture [about half of the Iberia soil], and hence, again, a comparative want of thriftiness, resulting in part from an inferior power of absorbing ammonia from the atmosphere.

As regards the subsoils, the close agreement of the analysis of three specimens, taken at random, so far apart, argues not only an equally close genetic relation, but is also strikingly illustrative of the groundlessness of the general objection urged against the utility of soil analyses, on the score of the supposed impracticability of obtaining representative specimens. Similar results have been obtained in the investigation of the soils of Mississippi, and can, doubtless, be reached in any region where the subsoils and soils are directly derived, by disintegration, from wide-spread formations; especially if the materials be very fine, and, therefore, thoroughly intermixed. No such uniformity of results, can, of course, be attained with manured soils, or with such as have been recently in cultivation; nor, for obvious reasons, can the results of the analses of *soils*, as a rule, agree as closely as those of subsoils.

Of the sub-soils before us, those of the Côte Gelée and Opelousas prairie agree most closely as to the two chiefly important ingredients, viz: potash and phosphoric acid; but they differ quite materially as regards the amount of lime, of which the latter contains twice the quantity found in the former, which, therefore, at the point sampled, would be the less thrifty of the two. This does not seem to accord with experience in cultivation; but then, a single specimen from each region cannot determine such questions.

In all three, the amount of potash is not over one-half of that usually found in upland subsoils in Mississippi; agreeing with the result observed in the Iberia prairie soil.

The Grande Côte soil is richer in potash, but poorer in phosphoric acid, than the two upland prairie soils. In the amount of lime it stands between the two others; but in none of the three does the amount of the latter substance approach that contained in the Iberia prairie soil, whose *subsoil*, were it is available for direct comparison, would show an amount even considerably larger. The same remark holds true of the magnesia, though this substance does not seem to be deficient in either.

Yet, although inferior to the best, there can be no doubt that, with proper culture, these lands can be made highly productive. As yet, their surface has but been scratched, and mostly with indifferent imple-

ments. With their balmy climate and easy tillage, unmenaced by washing and floods, the Côte Gelée, as well as the Opelousas prairies, cannot fail to become a second "garden," whenever the railroads now in course of construction, and others that will follow them, shall place this region in easy communication with the world's market, and with the makers of subsoil and steam plows.

THOSE MOUNDS.

From the dividing plateau just mentioned, the prairie slopes off to wards the heads of Bayou Cannes, and the very level prairie on the edge of which "Flattown" is situated. On this prairie we first observe, in considerable numbers, those singular rounded hillocks which dot so large a portion, both of the prairies and the wood lands of Southwestern Louisiana, and adjoining portions of Texas. With a maximum elevation of about two feet above the general surface, they have a diameter varying from a few feet to twenty or thirty; their number defies calculation. They do not show in their internal structure any vestige of their mode of origin; or rather, being totally devoid of structure of any kind; they merely prove by their material that there has been a mixing up of the surface soil with from two to four feet of the subsoil. They are altogether independent of formations underlying at a greater depth, and it seems impossible to assign to them any other origin than that historically known of their brethren in Texas, viz: that of *ant hills*. As to the physical or moral causes of the wholesale slaughter or emigration of this once teeming population, deponent saith not. Perhaps some of the aboriginal Attakapas tribes might, if consulted, still be able to bear testimony on the subject.

CHICOTVILLE.

The wooded uplands near Chicotville are evidently of a mixed geological character. While in some localities, wells and hillsides exhibit the unmistakable drift, in others, wells strike only materials equally characteristic of the Port Hudson group, such as fetid black and blue clays, fossil wood, leaves, etc. Doubtless the deeply-eroded surface of the drift formed in this region, a somewhat indefinite or deeply-indented shore-line of the Port Hudson marshes; hence a complicated interlacing of ridges, basins, and estuaries of the two formations. At some points, doubtless, the Grand Gulf clay and "rotten" sandstones may also be struck, as is the case to the westward of Pine Prairie, o the waters of the Nezpiqué. The unalloyed drift covering the Grann Gulf rocks may be seen, according to Hopkins, a few miles northd ward of Chicotville.

PINE PRAIRIE.

From the ridge or plateau on which the latter place is situated, a few miles' gradual descent southward, through oak uplands, with a pale yellow loam subsoil, takes us to the Pine Prairie, a gently rolling plain, dotted with clumps of Long-leaved Pine, which, if not equal in

size to some of its brethren in the woodlands, is equally far from the dwarfed condition in which we find it on the "meadows" of the Mississippi sea coast.* These pine prairies, of which this is the most easterly outlier, form an important feature in Calcasieu, as well as in portions of Texas. The soil here is greyish, ashy, full of bog ore spots; subsoil at six to eight inches, is sometimes a mass of black gravel, and underlaid at the depth of a few feet by a putty-like, very siliceous clay, almost impervious to water. The soil is very poor, the growth of grasses coarse, such as *Luzula*, *Carex*, *Juncus*, *Andropogon*, some *Paspalum;* while the *Aletris aurea*, *Allium mutabile*, *Linum Virginicum*, *Baptisia leucophœa* and *leucantha*, *Psoralea melliotoides*, and a variety of *Polygalæ*, impart to this barren prairie a much more cheerful aspect than is that of the green and fertile, but flowerless prairies of Opelousas. It is only by the aid of manure, however, that any crops can be raised on this soil.

Beyond the prairie we enter upon a belt of long-leaf pine hills of the usual character, possessing a yellow loam subsoil of fair fertility (as a pine woods soil); the pine timber is remarkably fine, and is occasionally replaced by short-leaved pine and oaks, indicating a stronger soil. This rolling timbered belt, borders the Nezpiqué on the east, with a width of from one to three miles.

THE "ST. LANDRY MARBLE."

In the bed of the Nezpiqué, as well as in that of Boggy Bayou, there are exceedingly characteristic outcrops of the materials of the Grand Gulf group, viz: solid greenish clay, and the jagged clay-sandstones, so common in the southwestern counties of Mississippi. But a few hundred yards from such outcrops is the now well-known limestone outcrop, which subsequent observations have enabled me to determine as being of cretaceous age. An analysis of this limestone will be given further on; it is remarkably pure, of a peculiar horizontally banded and fissured structure (whence it has received the name of "St. Landry Marble," a polished specimen of some beauty being in possession of the New Orleans Academy), and of fetid bituminous odor when struck. It is exposed in pits, dug at two points, about a quarter of a mile apart, a thickness of eight feet being visible; its dip here is about 30 degrees W. 40 S. Weathered surfaces show the horizontal structure and a granular, concretionary texture, but not a trace of fossils. Of the extent of this deposit nothing is known; but from the thickness and solidity of the portion exposed, it seems likely that enough is there to supply Southwestern Louisiana with excellent lime for a long time to come. In an agricultural point of view, this is of especial importance, and will not fail to be appreciated whenever the long hoped-for railroads shall have put this now isolated region in communication with the outside world.

*Mississippi Report, 1860, p. 370.

PINE FLATS AND "BAY GALLS."

West of the Nezpiqué, the pine woods are much less undulating, and the soil more whitish; and as we advance westward, they become almost a dead level, and full of boggy patches with crawfish holes and aquatic plants; among them the *Asclepias paupercula*, the vermilion-colored Milkweed of the seacoast marshes. The soil is whitish and very poor, fit only for pasture, and, perhaps, rice culture. Frequently there is a dense growth of Candleberry *(Myrica cerifera* and *Carlinensis)*, Bay Galls *(Laurus Carolinensis)*, and a variety of Whortleberries *(Vol-ciniuṃ)*; and where these prevail exclusively, we have impenetrable thickets, popularly designated as "Bay Galls," the undisputed resort of the bear, panther and wild cat.—Of these there are two main bodies. One on the east of Calcasieu river, in Townships 3 and 4, Ranges 2 and 3 west; is about fourteen miles long, and half as wide at its widest portion, of a spectacle shape, and distant about a mile from the Calcasieu river; the trail from Chicotville to the Bundick's Creek settlement crossing it at its narrowest point. It is drained by the western branch of Beaver Dam or Nezpiqué Creek.

The other "Bay Galls" tract lies nearly opposite, is of about the same length, north and south, as the other, but of a regular, oblong shape, only five miles in greatest width, and is drained by the heads of Mill Creek.

Almost the entire tract traversed from the Nezpiqué to the Calcasieu river, is uninhabited and uncultivated, save by crawfish, which bring up a siliceous subsoil, often perfectly white, putty-like, but mixed with small rounded concretions of bog ore.

Near the river the land becomes somewhat higher and dryer. The bottom is over a mile in width, much subject to overflow, but very productive. The timber is very prevalently Beech, also Magnolia, Bay, Sweet Gum, etc. A beautiful shrub, the *Styrax Grandifolium* (just in bloom at the time), is quite abundant.

The present deposit of the river is rather sandy; but the more ancient material in its banks is a quite heavy bluish clay, with ferruginous spots, such as is formed in Boggy Bayou and elsewhere, by the disintegration of the Grand Gulf clays. No steep bluffs of any consequence, and hence no outcrops of the older strata, seem to occur on this portion of the river's course. But near the mouth of Mill Creek, there is a small natural waterfall, which from the description and the nature of the case, is doubtless formed by the resisting Grand Gulf clays or clay-sandstones; such as cause similar phenomena elsewhere.

THE CALCASIEU PRAIRIE.

Near the line between townships 5 and 6, range 4 west, the level pine woods become more open, the pine smaller, and by a gradual transition we pass into the open prairie, dotted here and there with clumps of pine, which generally occupy some of the singular mounds before referred to. The pine prairie continues for about five miles, and is unoccupied save by herds of cattle; the houses of the herdsmen or

owners being in sight along the edge of the belts of timber which skir the water courses on either side. Farther south, clumps of Black-jac and Post-oak mingle with, and gradually replace, those of pin Around the heads of Serpent Bayou (which deserves its name so far a a redundancy of snakes is concerned), formed by extensive swamp flats, there is a belt of woods with an excellent soil. In these flat (the resort of numberless water-fowl), as well as in the lower levels o the open prairie, the usual place of Alder and Dwarf-willow, is occu pied by the *Styrax pulverulenta*. In the former localities it forms bushe five and eight feet high; in the latter it simulates the *Salix tristis* o the upland barrens, both in height and forlorn, dusty aspect.

Beyond the woody belt we again emerge upon the open prairie dotted with clumps of pine and oaks, and countless herds of cattl and horses, but no settlements until we again approach Serpent Bayou. The soil is manifestly better than farther north, a species of *Paspalum (barbatum?)* called "Gazon," by the Creoles, forming the predominan pasture grass; which is highly prized by the stock raisers, especially for winter pasture. Pretty good well water is obtained here at fifteen to twenty feet.

Serpent Bayou has little bottom proper, but is bordered by a narrow strip of black semi-alluvial prairie. The black soil is six to eight inches deep; it is sparsely timbered with Sweet Gum and Willow Oak and seems quite fertile.

South of the crossing of Serpent Bayou, the prairies resume their usual aspect; and about three miles from the bayou, I took a specimen of the soil, avoiding the mounds in the open prairie.

VEGETATION: Clumps of Black-jack and Post Oak, and long-leaved Pine, scattered over the prairie. On the grassy surface, the prevalent plants are the two or three oft-mentioned species of *Paspalum*, some *Luzula*, *Juncus*, *Andropogon; Leptopoda fimbriata*, *Obeliscaria laciniata*, *Rudbeckia hirta*, *Echinacea purpurea*, *Silphium squarrosum; Baptisia leucophæa*, *Psoralea melilotoides*, *Mimosa strigillosa*. *Polygala*, two species; *Styrax pulverulenta*.

Depth taken, ten inches.

Soil gray, somewhat ashy, with brown ferruginous spots, and small particles of bog ore, which sifted out, amounts to 1.5 per cent.

Saturated with moisture at 13.4° Cent., it lost 3.16 per cent. of water at 204°, and thus dried consisted of—

Insoluble Matter	92.63	94.66
Soluble Silica	2.03	
Potash		0.15
Soda		0.04
Lime		0.26
Magnesia		0.14
Br. Oxid. Manganese		0.04
Peroxid of Iron		1.11
Alumina		1.71
Phosphoric acid		0.04
Sulphuric "		0.06
Water and organic matter		2.61
		100.82

According to this analysis, this soil is not as poor, on the whole, as might have been expected; save as regards phosphates and magnesia, in which it is very deficient. It is sadly in need of something to render it more retentive, i. e. clay or vegetable mold; but if properly drained, might be susceptible of profitable improvement and cultivation by some green manuring and use of bone-meal. Like similar soils in South Mississippi, it now bears only small-seeded plants; there being a want of the seed-forming ingredients.

As we advance southward, we occasionally find sandy ridges, timbered with rather an indifferent growth of pine, crossing the road; and between these, wet flats, in part even peopled with alligators, become more frequent. At the same time the herbaceous vegetation assumes more and more the features of the coast region, in the appearance of the Flowering Grass *(Dichromena)*, and other plants of similar import.

LAKE CHARLES.

The prairie continues almost unchanged in character up to English Bayou, in which we find outcrops of a stiff calcareous clay, lying but a few feet beneath the general surface. On crossing the bayou, the clumps of trees disappear, the prairie being a perfetly level, treeless plain, with a darker and heavier, and evidently better soil, on which fine crops of corn are grown.

At several points on Lake St. Charles, near the town, there are outcrops of a stiff, red laminated clay, near the water's edge. It is generally overlaid by ten to twelve feet of indefinite sand strata, and greatly resembles some of the clays at Côte Blanche.* Overlying the sand and immediately beneath the subsoil, lie two and-a-half to three feet of gray "joint" (i. e. massy) clay, often with calcareous concretions. The same strata are, of course, struck in wells, sometimes with oysters and other marine shells; and the upper clay stratum with calcareous concretions crops out repeatedly in washes, on the road from Lake Charles to the Sulphur mine.

The phenomena at the latter point, as well as the general features of this region, having already been sufficiently described heretofore, by others as well as myself,† I will merely add that the examination of two large shell-beds on the lake led to the same conclusion already reached regarding those on the Mississippi coast, viz: That being full of the vestiges of human handiwork, such as pottery and charcoal, and consisting almost entirely of edible shells *(Gnathodon* mainly and *Unio)*, with occasional bones of small animals, and a few land-snails (doubtless accidentally introduced), they must be considered as the relics of human efforts to sustain life at the expense of the bivalve creation.

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*Smithsonian Contr. to Knowledge, No. 248.

†NOTE.—See my "Preliminary Report of a Geological Reconnoisance of Louisiana." in DeBow's Review, for September, 1869. Also, Am. Jour. of Science, for November, 1869; and the Reports of the Geological and Topographical Survey of Louisiana, by Professors Hopkins and Lockett.

I will also remark that while, as a rule, the bottoms of the Calcasieu and Sabine, above the latitude of Lake Charles, do not materially differ from those of other rivers in the Gulf States, although usually laid down on maps as skirted by broad marshes; there are on the West Fork of Calcasieu some grassy bogs resembling sea-marsh in their aspect; as is the case on the main Calcasieu below the lake, on Bayou Choupique, and others in that region.

NORTHWEST CALCASIEU.

North of the West Fork, level pine woods, with occasional bogs or small prairies, prevail with little change save a gradual rise from the sea-level, and slightly greater undulation as we progress northward. Vegetation is about the same as in the boggy pine woods near the "Bay Galls." Quite a variety of *Polygalæ* occurs; also the beautiful *Rudbeckie maxima*, the *Styrax pulverulenta*, too, is occasionally to be seen.

On approaching Dry Bayou, hills appear, and after crossing it, the plains of the coast are changed into gentle rolling pine woods. The marsh milkweed disappears, but the *Dichromera* continues, and with it occur the *Eriocaulum villosum* and *decangulare*, which were not observed farther southwest of the Calcasieu. Here, also, the *Sarracenia variolaris*, or Pitcher-plant appears, but not the *S. purpurea*. The *Stillingia sylvatica* (Queen's Delight), *Valeriana* (*Pauciflora?*) and *Cnidoscolus stimulosus*, (here often three feet high, while in Mississippi it rarely exceeds one foot,) are quite prevalent here as well as more or less northward to Red River. Except in so far as the country gradually becomes more undulating as we advance northward, there is very little change in the face of the country (the pine forest being broken by settlements only at long intervals), until we approach the base-line in R. 9 W., where we find the regular "Orange Sand" pine hills with gravel, red hard-pan and ferruginous sandstone cropping out on the abrupt hill-sides. Springs, which are very rare farther south, here flow abundantly, being shed by gray pipeclays forming the base of the hills; and a few miles farther on, near the mouth of Miller's Creek into Taylor's Creek or Bayou Foury, the Grand Gulf clay forms high bluffs of very characteristic material.

Traveling, as the party did, mainly on a dividing plateau, where outcrops could not be found, the line between the Port Hudson and Grand Gulf territory could not be directly determined. The line as originally laid down by me, and adopted by Prof. Hopkins, in his Geological Map of the State, is, therefore, based upon the connection of the outcrops near Chicotville, then near the mouth of Mill Creek into Calcasieu river, and the point on the Sabine (Salem), given as the limit between the quaternay and tertary, by Prof. Buckley, of Texas. In Mississippi and East Louisiana, likewise, this limit is difficult to determine, and in a measure arbitrary, since the two formations lie conformably, or nearly so, in a level country where wells or accident only can give access to the more ancient strata. Probably outcrops

of the Grand Gulf clays may be found on Lower Bundick's Creek, on the Little Calcasieu, or the West Fork.

THE ANACOCO REGION.

After crossing Bayou Zoury, the country again becomes level, with a very heavy clay soil of a red or pale tint; small Black-jack appears among the Pine and Sweet Gum in the lower places.

Immediately beyond Huddleston or Petersburg, we meet patches of dark-colored prairie soil, with Crab-apple and Wild Plum; small calcareous gravel appears in roadside washes. Further on, the prairie soil appears in larger patches, irregularly distributed along hillsides and in valleys, as a consequence of its origin in a stratum of clay marl, which crops out in branches a few miles north of Huddleston. This stratum is about five feet thick, and the exact counterpart of the calcareous stratum first observed by me on Pearl river, in Marion county, Mississippi (Barnes' marl).* Here, too, it is substantially a heavy greenish clay, irregularly traversed by veins of concretionary carbonate of lime, of the "Agaric mineral" character; rarely somewhat crystalline. Of this it contains probably from four to eight per cent.; but nowhere could I discover a trace of a shell, or any other fossil.

Where this stratum crops out on a hillside, it forms by its disintegration and sometimes intermixture with the sandier materials washed from above, a streak of black calcareous soil, easily tilled, and highly productive. Where, as on the Anacoco prairie itself, the disintegrated marl stratum forms the surface, the soil is heavier, but from its tendency to crumble by alternation of wetting and drying, not difficult to cultivate if plowed at the proper time. It produces forty bushels of corn and a bale of cotton per acre; the cotton is small but well bolled, not much subject to rust, and the soil lasts remarkably well so long as it is not washed away, which is apt to happen—though it is rarely plowed over four inches deep.

Above as well as below the calcareous stratum, lie tough clays, giving rise, respectively, to red and pale-tinted "hog-wallow" soils, said to be of very little "account"—difficult to till, and unthrifty. Some hillsides, when freshly plowed, have a very variegated appearance; the common yellow loam soil, perhaps, being on top; next, the red "hog-wallow;" below it a coal black band of prairie soil, which in its turn gradually shades off into a pale, unpromising clay, at the foot of the hill.

Bodies of land on which this soil prevails, varying from a few acres to several sections in extent, occur sporadically at numerous points between the West Fork of Anacoco and the heads of Calcasieu river—how much further east, I have been unable to learn. It is noticeable that while in the southern portion of their region of occurrence, these patches mostly lie at or near the level of the creek bottoms, they rise higher and higher on the hillsides as we advance northward; owing, doubtless, to a slight southward dip of the stratum from which their soil is derived. At John Smart's, section 33, township 3, range 9 west,

* See Mississippi Report, p. 179.

it forms the crest of a ridge bordering Prairie Creek on the east, and thence extends, with a width of from one-half to one mile, for about three miles along that stream. The black soil here is about twenty inches deep without sensible change. In washes, we observe the calcareous clay or marl forming the subsoil for a few feet, when a heavy non-calcareous clay is struck.

Rocky knolls and spurs showing outcrops of the characteristic clayey sandstones of the Grand Gulf group, occur occasionally on the ridges in the prairie district. Between Prairie Creek and the West Fork of Anacoco, these outcrops become more abundant, and the heavy clay soil frequently appears on the hillsides. But it is non-calcareous, and bears a poor scrubby growth of Black-jack Oak, while the summits of the ridges are of a sandy pine-hill character. At Kirk's Mill, on the East fork of the Anacoco (section 10, township 3 north, range 9 west), we have a long hillside outcrop showing a great variety of the clays and "rotten" sandstones of the Grand Gulf age.

Between the two prongs of the Anacoco we have a rather level pine woods plateau, with occasional outcrops of gray clays on hillsides, giving rise to a poor, stiff, tawny soil, and at times, the heavy red subsoil already mentioned. On the hilltops, the Drift often overlies very characteristically. A small tract of slightly calcareous clay soil occurs near the slope towards the West Fork, but is timbered with small Black-jack Oak and Pine—there is no black prairie. On the stream itself, there appears the peculiar sandstone with grains imbedded in an opalescent matrix, so characteristic of the outcrops at Grand Gulf.

After crossing the West Fork of Anacoco, we find for some distance only sandy pine hills. But soon the Grand Gulf clays reappear, and on approaching within a few miles of the Toreau, outcrops of "rotten" sandstone become very common on the brows of the hills, which become quite high and abrupt. At one point, a high and steep hill presents on its slope a complete assortment of all the sand and clay-stone materials of the group, observed by me in Mississippi and Louisiana. But neither here nor anywhere in the area of the Grand Gulf group, as here traversed, was there any trace of zoogene fossils to be detected. Very imperfectly preserved vegetable remains alone could occasionally, and very sparingly, be noticed.

The Drift, from the Bayou Zoury up to this point, presents the usual character, capping almost all the higher ridges, and frequently forming their body also. Its only peculiarity in this region is the frequent occurrence of very coarse, white sand, resembling Liverpool salt—its material being chalcedony and quartzite.

THE TOREAU REGION.

Beyond the Toreau, toward Sabinetown, the long-leaved Pine disappears, being replaced by the short-leaved Pine and a variety of upland oaks—among them the White Oak. The change of formation is further indicated by the appearance of a heavy, red subsoil, and occasional patches of limy prairie, with vestiges of shells; while in

ravines and in the bluffs of branches, we find the characteristic limestone of the Vicksburg marine Tertiary, alternating with greensand marls containing poorly preserved shells.

The ridge soil, of which a specimen was taken, about section 26, township 5 north, range 12 west, is of a dark mouse-color, and moderately heavy to about eight inches depth; then follows a deep orange-red, and rather heavy subsoil. The timber near this spot was short-leaved Pine, Hickory, Elm, Ash, Red, Spanish and much White Oak.

About a mile further on, there is a denuded hillside, where the drift is exposed, and is peculiarly rich in fossil wood—*Palm* wood among numerous other species. Not far from this we find in branches, not marl, but brown laminated and blue sandy clay, with fossil leaves pretty well preserved, and closely resembling the materials lying at the foot of the Vicksburg bluff; and similar materials continued to be seen at the lower levels up to the edge of the Sabine bottom. On the hills, however, we find, about section 26, township 5 north, range 12 west, and for some miles north and south of that locality, a ledge, twelve or eighteen inches thick, of a dark ferruginous clay rock, cleaving in laminæ, about a foot or two below the surface of the ground, which is strewn with ferruginous pebbles of all sizes. Beneath the ledge of rock lies a dark, highly ferruginous, stiff clay; this, as well as the rock, contains numerous casts of shells, amongst them *Arca Mississippiensis*, of Vicksburg. The soil resulting from the disintegration of these materials, is stated to be very productive of grain crops, and very lasting; it is said to occupy a strip one-half to two miles wide by five to six miles in length, north and south At some points the rock strikingly resembles the matrix of the Red Bluff fossils on the Chickasawhay river;* but the abundance of *Arca Mississippiensis*, which characterizes it here, seems rather to assign it to the top of the Vicksburg profile.

Altogether, the Toreau country possesses no mean attractions in an agricultural point of view. The uplands are of very fair quality. and the numerous valleys may, to a considerable extent, be accounted first-class lands. The country becomes gradually less undulating as we approach the Sabine, and the slope into the bottom is gradual.†

The latter is about a mile wide, and its actual character contrasts rather strongly with that usually given it in maps, where it is represented as a broad band of marsh. In matter of fact, it is rather uncommonly undulating, and timbered mainly with Oaks mingled with short-leaved Pine, and at some points a good deal of Beech. Nor, according to all the information I could obtain, does it assume a character different from the usual one of streams in the Gulf States, above the latitude of Lake Charles.

SABINETOWN.

Sabinetown, Texas, is situated on a bluff 150 feet high, falling off steeply into the river. Hence it affords one of the best opportunities

* Mississippi Report, 1860, p. 135.

† Ibid, page 142.

for studying the character of the tertiary strata of the central portion of Louisiana, and the detailed section of the bluff, as shown just opposite the town, is too instructive to be omitted here.

Profile of the Bluff at Sabinetown, Texas.

No.	MATERIALS AND CHARACTER.	FEET	FORMATION.
14	Ferruginous sandstone, and conglomerate of pebbles with fragments of silicified wood	6	Drift.
13	Ferruginous sand, of the usual Drift facies, with two or three ledges of ferruginous sandstone	18	
12	Yellow and variegated sand, with clay laminæ interspersed	6	Mansfield Lignitic (Foot of Vicksburg Bluff.)
11	Gray or brownish laminated clay, with yellow (ochreous) cleavage planes, and a few sandy layers	25	
10	Yellow and variegated sand, with clay bands at intervals of about twenty inches	30	
9	Gray laminated clay with Selnite, and ferruginous stratification lines at intervals of ten inches	12	
8	Greenish ferruginous sand with clay laminæ	3	Jackson. (Marine.)
7	Ferruginous, concretionary sandstone, porous, fossiliferous	3	
6	Solid blue sandy clay	3	
5	Brown laminated clay with Misy	1	
4	Blue fossiliferous limestone, sandy, with *Rostellaria velata*	2	
3	Greenish sand, alternating with clay laminæ	6	
2	Blue calcareous sandstone, fossiliferous	2	
1	Greenish sand, as far as visible	2	

The general dip of the strata is decidedly southward, but its amount can scarcely be measured on the rough surface of the ledges. It may be as much as two or three degrees.

The stratification is frequently quite irregular, partly owing to disposition in basin shape, and partly to dislocations and subsidences, the limits of which are usually marked by laminated ferruginous veins, with knots and curves.

At the foot of the bluff, where at high stages of water it is difficult to find a passage, is lined with blocks of dark colored rock, tumbled from above. These are mostly derived from No. 7 of the section—a porous, concretionary, ferruginous sandstone, with casts of fossils, now unrecognizable. There are, besides, blocks of hard limy sandstone or sandy limestone, derived from Nos. 2 and 4. The former is generally poor in fossils, the latter in places very rich, and the fossils well preserved, but very difficult to detach from the rock. Among them, a small variety of *Rostellaria velata* is the only fossil usually characterizing the Jackson group. But this, at the time of my visit, I failed to identify, and was inclined to consider the fauna found here more nearly related to the Vicksburg than to the Jackson group. But at a subsequent visit, Prof. Hopkins found on a tributary entering the Sabine just above the ferry, a bed of shells bearing most distinctly the Jackson character. While it is thus proven that the lower (marine) portion of this profile is of the latter age, the upper (lignitic) part is thereby par-

allelized to the lower division of the Vicksburg bluff, to which it bears a close lithological resemblance. And if we define the area actually underlaid here by the Vicksburg marine rocks proper, we cannot assign to it, on an average, a width greater than about three miles in a northwest and southeast direction.

At another point on the tributary mentioned above, I found stratum No. 4 of the preceding profile, very poor in fossils, but exhibiting rounded concretionary masses of sandy limestone, traversed by veins of calcareous spar. They are undistinguishable from those brought up from the oil bearing stratum of the Calcasieu Sulphur Well;* and a comparative analysis of the two rocks, while showing a very close correspondence with each other, and the other tertiary limestones examined, exhibits the wide difference in composition from the crystalline limestone associated with the sulphur; that, in its turn, is chemically identified with the other cretaceous limestones of the State.†

A bed of lignite, said to be of excellent quality and at least ten feet thick, crosses the river about two miles north of Sabinetown, causing rapids. This shows the marine strata to be of little thickness, and probably incontinuous within small areas.

SABINE PARISH.

Leaving Sabinetown on the Manny road, we ascend into the hilly country immediately after leaving the river, the bottom being on the Texas side. We meet again the stiff, glaringly red subsoil and drift outcrops of rather a clayey character, on the hillsides. The vegetation is less luxuriant than that seen further south, on the Vicksburg territory—there is more Pine, Post Oak and Black-jack, and less White Oak, Gum, Ash, etc.

At various points between Sabinetown and Manny, we find in the bluffs of streams outcrops of more or less lignitiferous clays and sands, associated quite frequently with large concretionary masses of a very hard and fine-grained, oftentimes cherty, but mostly non-fossiliferous limestone. On Bayou San José, limited beds of lignite occur at several points; while on the heads of Bayou Negrete, e. g. near Dutton's tannery, and in the neighborhood of Manny itself, lime of a good quality was burned. A very detailed survey alone could map out the numerous isolated points of occurrence of the several materials, which have evidently been formed in shallow estuaries, lagoons and marshes, frequently interchanging their places in the course of time.

It had been my intention to proceed from Manny to Natchitoches; but as it became obvious that the party was traveling in the direction of the *strike* of the formation, while the objects of the expedition required that it should be *crossed* as frequently as possible, we faced to the left about in the direction of Pleasant Hill and Mansfield.

About two and a half miles north of Manny, the long-leaved Pine appears again on the ridges, mingling with the short-leaved species,

* See my "Preliminary Report," page 12.

† See analyses, below.

and Oaks; which are thickly hung with Long Moss. Patches of the latter are said to extend for some distance along the crest of the dividing ridge between Red and Sabine rivers.

Unfortunately, the road traveled runs almost altogether on this level ridge, rendering observations of the geological formations difficult. The deep red subsoil continues to be seen; the soil is in some places quite poor, bearing only Pine with small Black-jack and Post Oak; but mostly it bears a good growth of other Oaks, and is of fair quality.

According to information given by Mr. Isaac Rains, at the Armstrong settlement (section 35, township 9 north, range 11 west), outcrops of limestone exist two miles south of that point, and again fifteen miles in an east by north direction, on the Natchitoches road. In the neighborhood itself, lignitic clays and sands, as well as lignite beds, are found in the wells and water-courses. At one point, a lignite bed was found four feet in thickness; in other wells, two strata of two feet each, etc., at depths varying from thirty-five to fifty feet, according to the surface location. Gypsum occurs in rosettes in the laminated clay, and often contaminates the water of wells passing beyond the drift, which covers the ridges, here as elsewhere, to a variable depth. Its ferruginous sandstone is common on the hills, as is also silicified wood. A good deal of iron ore, also, is found in the upland soils at some points—the surface soil is generally light, but the subsoil heavy, being derived from the tertiary clays. Hence the land, though productive and lasting, is a good deal influenced by the seasons. On the lower slopes and at the foot of the ridges, springs are abundant, being shed by the clay strata after percolating through the drift; hence the streams are kept flowing throughout the year.

It appears that the "soda" made by Governor Allen during the war, was obtained by digging pits in "salty spots" in the Sabine flat (about two miles from Myrick's Ferry), and evaporating the water thus collected; or else by leaching the surface earth. Common salt, also, was made at other spots in the same manner.

DOLET HILLS—IRON ORES.

The same general character of soil and country continues up to Pleasant Hill; outcrops of lignitic clay are reported as occurring all along in the streams at the foot of the ridge, but no limestone. At Pleasant Hill (whose location in a gently undulating and productive upland region justifies its name), the party descended from the main ridge, making a detour through the hilly country on the Red River side (part of the "Dolet Hills"), in order to gain access to the outcropping strata in the ravines. These were found to be lignitic clays and sands of variable character. The hills are finely timbered with tall Pines (short-leaved), Oaks and Elm. At some points there is for a mile or so a very gravelly soil, the gravel being exclusively of a concretionary ferruginous material; and on the brows, as well as sometimes on the top of the ridges, there crops out large ferruginous nodules; partly of

ferruginous sandstone, partly genuine geodes and concretionary masses of brown hematite. They chiefly occur where the stiff, red subsoil underlies, which is itself filled with ferruginous gravel, sometimes of large size. In washes on the hillsides, clayey strata of the Drift age are shown underlying; in the beds of streams we sometimes find what appear to be older strata, but in fact are mere conglomerates of ferruginous gravel and clay, consolidated.

Another patch of ferruginous gravel occurs between six and seven miles from Mansfield. The soil is clayey, about five inches deep, bearing rather a poor growth of Pine, Post and Spanish Oaks, with some Hickory. The subsoil is of a bright orange tint, full of ferruginous gravel; and on the brow of the hill ferruginous nodules crop out about twelve inches under ground.

An analysis of a fair average specimen of the ferruginous gravel occurring near Pleasant Hill, gave the following result:

Peroxid of Iron.....	57.44
Insoluble matter (Sand)..	35.19
Water and Alumina.....	7.37
	100.00

Doubtless Iron could be profitably manufactured here by sorting the ore somewhat; and the erection of an iron furnace in this region was contemplated by Judge Robertson, of New Orleans, during the war.

Lignite, also, is reported as occurring rather abundantly in this region; one locality being eight miles north of Pleasant Hill.

Shallow wells (fifteen to eighteen feet deep) in this region have good water, as they remain within the Drift materials. But where the gray lignitic strata are reached, the water is hard (from Gypsum) and sometimes fetid. Springs, however, are quite abundant, and the streams flow rapidly and cheerily.

MANSFIELD.

At Mansfield (where the party was most kindly taken care of by Dr. R. F. Gibbs), there is a highly interesting outcrop in a deep ravine just west of the town, which is situated on a broad, level ridge, falling off rather steeply to the westward. This outcrop differs from all seen heretofore in the lignitic formations of the Southwest, in exhibiting a stratum of limestone of fresh-water origin; and in this regard resembles strikingly the interior basins of the Far West.

Profile at Mansfield.

NO.	MATERIALS.	FEET.
4	Indurate, clayey sand (or "hard-pan") of the Drift age..	15
3	Clay and Sand, gray, interstratified.....	6
2	Impure, laminated limestone, with leaves.....	2
1	Stratified, gray clayey sand, and gray or whitish laminated clay, interstratified. One clay stratum six feet thick, the rest a few inches.....	30

The limestone No. 2, so far as seen, is void of shells, but in its lower portions especially, which are laminated, there is an abundance of lignitized impressions of stems and leaves—mostly fragments, and irrecognizable. Its upper portion is the purest, yet scarcely so as to fit it for lime-burning, save for agricultural purposes. This stratum crops out on many hills around Mansfield, especially northward. Dr. Gibbs informed me that it extends at least eight or ten miles on the Shreveport road, and perhaps to that place.* On a ridge north of the town, at a lower level, apparently, than the limestone, fragments of a ferruginous shale lying on the slope, exhibit abundant and very perfect impressions of leaves. It is an interesting fact that Hopkins also found a leaf-bearing stratum associated with the limestone at Shreveport. I hope, therefore, that this region will furnish the material for comparison both with the tertiary flora of Mississippi, and with that of the interior basins.

It seems that lignitic strata crop out on both sides of the dividing ridge from Pleasant Hill to Mansfield, and towards Shreveport. The bluff on the Sabine at Logansport, according to all accounts, is similar to the profile just given. A bed of lignite exists a few miles southwest of Mansfield, and several others in the Dolet Hills, northeast of Mansfield; also at Granning's Ferry, on the Bayou Pierre.

Finding the time to be getting short, the party here determined to cross Red River, so as to examine the salines of North Louisiana, and thence re-cross the marine formations, on the route to Harrisonburg

DOLET HILLS—GRANNING'S FERRY.

On the way from Mansfield to Granning's Ferry, the country differs little from that seen between Mansfield and Pleasant Hill; becoming more broken as we approach the river, and the body of the hills consisting of lignitic clays and clayey sands, with some Drift with ferruginous sandstone capping them. The deep red subsoil appears frequently, but is often covered by a pale yellow loam, which is considered the poorest soil hereabouts.

A specimen of the heavy red subsoil was taken on a hillside about two miles from the ferry. The surface soil is only a few inches deep, a little more sandy and grayish; depth at which the subsoil was taken ten inches. Vegetation, a rather indifferent growth of upland oaks.

The subsoil, saturated with moisture at 71° Fahr., lost 8.98 per cent. of water at 400°, and thus dried, consisted of:

*This is confirmed by Prof. Hopkins, who found the profile at Shreveport very similar to that at Mansfield.

Insoluble matter	71.800
Silica soluble in Na. Co. 3	7.450
Potash	0.367
Soda	0.008
Lime	0.055
Magnesia	0.449
Br. oxide of Manganese	0.056
Sesqui oxide of Iron	8.966
Alumina	7.119
Phosphoric acid	0.179
Sulphuric acid	0.007
Water and Volatile matter	4.820
	100.786

For so clayey a soil, this one is rather poor in potash, while comparatively rich in phosphoric acid. The amount of lime is too small by far to render such a soil as this thrifty; and the application of lime to it is at once indicated as an important means of improvement. Being very heavy in cultivation, deep and thorough tillage will be particularly essential.

Doubtless, much of the heavy red subsoil mentioned repeatedly, is richer in nutritive ingredients than the one analyzed; none probably is poorer. But I have no doubt that the necessity for applying lime exists in all, judging by the usual vegetation.

The lignite bed near Granning's Ferry is on a hillside, not well exposed; from three to four feet thick, and of good quality. Its extent cannot be ascertained without digging or boring.

The right bank of the Bayou Pierre at this point is a steep bluff of whitish laminated, almost chalky looking, clay, some ten feet above high water mark. It resists washing considerably, and this explains the existence of elevated ridges between Bayou Pierre and Red River both above (in the lake) and below this point [the Macdoan Hills]. Since, a few miles inland, the clay occurs on hill-tops elevated at least 350 feet above the river, this number represents the minimum thickness of the formation in this region.

RED RIVER BOTTOM.

The banks of most of the bayous exhibit characteristically the reddish tint of the Red River alluvium. Thus Boggy and Grand Bayous, along which the party passed to Grand Bayou Landing, and thence turned down stream to cross at Coushatta Chute. Red River was above its medium stage of water, and hence the observations along its banks were not as satisfactory as could have been desired. Still, the fact that the channel is in a great measure cut into a formation older than the alluvium, became obvious in the course of a few miles. The fresh alluvial deposits bear predominantly the character of a reddish loam, alternating frequently with streaks and sheets of red clay possessing the wavy structure. Sometimes these loamy deposits, from which the lighter class of the bottom soils is derived, would continue down to the water's edge. But more generally, at a depth varying from seven to twelve feet, a different kind of material would appear—heavy red or blue clays, or both alternating; with streaks of calcareous

concretions often marking the stratification lines, which are *not* wavy on the small scale. The visible thickness of such strata frequently exceeds twenty feet; and it was stated by intelligent persons that they continued the same, or nearly so, to low water's edge, making up an aggregate thickness of thirty-five or forty feet.

The following profiles will illustrate the condition of things:

Sections of Red River Banks.

FT.	I. 6 MILES ABOVE COUSHATTA LAND'G	II. 4 MILES ABOVE COUSHATTA.	FT.
5	Reddish gray sandy loam.	Reddish gray loam.	7
2	Gray, indurate loamy sand.	Stiff red clay.	½
3	Loam, like top stratum.	Reddish gray loam.	1
2	Stiff red clay.	Stiff red clay.	1½
3	Gray Loam.	Yellowish gray loam.	1½
10	Red loam, coherent to water's edge.	Stiff red and bluish clay, with calcareous concretions; alternating in strata from 1 to 3 feet thick.	17

FT.	III. 3 MILES ABOVE COUSHATTA.	IV. 2¾ MILES ABOVE COUSHATTA.		FT.
8	Reddish and variegated loam and clay—river deposits.	Reddish loam etc. River deposits.		18
½	Stiff red clay.			
½	Reddish loam.			
3	Stiff red and blue clay.			
4	Sandy hard-pan, in ledges.			
3½	Gravel conglomerate, basin shaped: coarse above, fine below. Farther on, pure sand, partly conglomerated into ferruginous rock.	Stiff brown clay.	Cypress Stumps	1
		Yellow loamy sand.		4
1	Stiff red clay	Brown clay with roots and leaves.		
1.	Blue clay, to water's edge.			

The red clay occurring in the lower portion of these profiles, is quite similar to that which is now formed by the back-water of the river, and may be seen where the undoubted river deposits are exposed. But the sheets of clay so formed, as might be expected, rarely exceed a few inches in thickness, and show a wavy surface. Nothing like the heavy, uniform strata of stiff red and blue clays, which are exhibited in the river banks continuously for miles, are now formed by Red river.

The color apart (the blue clay being doubtless derived from the red by a simple process of reduction), these banks at once recall the profile at Port Hudson; while at some points, they could scarcely be distinguished, color and all, from portions of the profile at Côte Blanche. Here as there, the lime of the paludal fauna has doubtless been dissolved and formed into concretions by maceration.* At one point only were well preserved fossils found, viz: in the gravel conglomerate of section No. III (above); they were a *Unio* and a *Paludina*. A few smaller land shells *(Helix, Helicina, Pupa)*, occur in the overlying strata.

It thus appears that the valley of Red river, like that of the Missis-

* Am. J. Science, Jan. 1869, p. 81; Smiths. Contr. Knowl., No. 248, pp. 11 and 12.

sippi, was converted into a swampy estuary at the time of the Champlain depression; the cypress stumps in Profile IV completing the analogy. It is stated that the banks maintain the same aspect up to Shreveport at least; and, as was subsequently ascertained, similar materials underlie the whole of the level lake country bordering on Red river, the color of the clays being, however, mostly blue or gray —a change readily understood.

RED RIVER SOILS.

There are in this portion of the Red river bottom, four chief varieties of soil, to which my attention was called by Maj. Dickson, a highly intelligent and progressive planter, near Grand Bayou Landing.

1. *Frontland Soil.*—Near the river and the main bayous, there is a yellowish red or reddish loam soil, light and easily tilled; deep, and very productive. In the "back bottom," farther from the channels, this soil becomes gradually heavier and more difficult to till, and forms

2. *Back Bottom Soil.*—Also very productive, and, doubtless, more lasting than No. 1. Both obviously alluvial.

3. *Bottom Prairie Soil.*—A black, calcareous soil, fully twelve inches in depth; timber, large Ash, Water Oak, Cottonwood, Hackberry, and Honey Locust. Occurs in patches; very productive—"a capital soil."

4. *Waxy Soil.*—Also in patches—an exceedingly heavy, close, intractable clay, mostly in low ground. It bears a curiously stunted, or rather stationary, growth of Hackberry, Ash, and Elm; trees thirty years old being no larger than we usually see them after three or four; besides these, it bears large Overcup Oaks. It seems to be practically worthless, at least for the present.

The last two soils are doubtless derived from the older clay strata; No. 4 from the stiff red and brown, non-calcareous clays, while No. 3 is similar to the "buckshot" prairie soil of the Tensas bottom, and derives from the lighter calcareous clays of the Port Hudson age.*

The following analyses give some light on the peculiarities of these soils, and of the materials concerned in their formation:

	Reddish ALLUVIAL LOAM.		*Red* CALCAREOUS CLAY.		*Dark* BOTTOM PRAIRIE.	
Insoluble Matter	90.48	94.48	55.75	63.22	78.18	84.71
Sillca, soluble in Na CO_3	4.00		7.47		6.53	
Potash		0.22		0.46		0.61
Soda		0.01		0.36		0.06
Lime		0.22		8.07		0.49
Magnesia		0.59		5.66		1.04
Br. Ox. Manganese		0.38		0.08		0.25
Peroxid of Iron		1.69		5.98		3.30
Alumina		1.41		6.68		4.23
Phosphoric Acid		0.22		0.26		0.15
Sulphuric Acid		0.04		Trace.		0.01
Carbonic Acid				3.91		
Water and Vol. Matter		1.29		5.82		4.92
Total		100.55		100.50		99.78
Hygroscopic Moisture		3.05				8.32

* On this subject, see a paper "On the Geology of the Miss. Bottom," by E. A. Smith, in Proc. Am. Ass'n Adv. Sci., 1871, p. 252.

The prominent characteristic of all these materials is the comparatively large amount of lime contained in them; and contrary to all expectation, they are poor in sulphates. The great fertility of Red river lands having been usually ascribed to the gypsum carried down from the great gypsum beds above, this is an important fact. The lime may have been originally dissolved in the shape of gypsum, and decomposed *in transitu* into carbonate of lime and soluble alkaline sulphates.

It is not often that we find in a deposit or soil yielding over 94 per cent. of insoluble residue, so large an amount of the important nutritive ingredients — potash, phosphoric acid, and lime; the great thriftiness of the alluvial soils of Red river is thus explained. The back bottom soils (No. 2) probably contain more potash, and may be more lasting than the frontland soils; whose depth and easy tillage, nevertheless, render them very desirable.

The black bottom prairie soil closely resembles in composition the "buckshot" soil of Coahoma Co., Miss., analyzed by Dr. Smith (l. c., p. 260). The relatively and absolutely large amount of lime in these soils accounts for their extraordinary thriftiness.

THE BLACK LAKE COUNTRY.

Crossing Red river at Coushatta Landing, where the uplands approach the river pretty closely, the party proceeded on the Vernon road. The red clay subsoil of the country south of the river, soon reappears in the slightly rolling uplands which form a low dividing plateau between Red river and the Grand Bayou of Black Lake. It is timbered with short-leaved Pine, Post, and some Spanish Oaks, and scrubby Black-jack—a poor and whitish soil in the lower portions, where *Phlox glaberrima* and Candle-berry appear; but pretty good where the Spanish Oaks are large. At the higher points, freestone wells may be had in the Drift materials, whose characteristic ferruginous sandstone is common on the ridges. But in many cases, the lignitic clays and lignite, with flattish, hard, and sometimes fetid water, are struck.

Black Lake bayou flows divided into numerous branches separated by swampy flats, appearing very much as though the lake had reached much farther inland in times not remote. Water, coffee color.

Beyond Bayou Castor, the country becomes more hilly, and the hillsides are very pebbly. The pebbles are often cemented into a kind of pudding-stone by brown hematite; but the latter does not appear in mass.

KING'S SALT WORKS.

The salt works heretofore owned by Mr. King, but now by Mr. Wardlaw, are situated on S. 35, T. 15, R. 8 W., close to a rather extensive salt lick in the level hommock of Bayou Castor, where salt is constantly blooming out on the surface. Here, during the war, a number of pits were dug for salt water, twelve to fifteen feet deep. From most of these only white soil and gravel has been dug, but two

or three have also furnished a soft, gray, calcareous mass, containing a multitude of small oysters, and to my great surprise, very perfect specimens of *Gryphæa Pitcheri*, and of *Exogyra costata*, two leading shells of the cretaceous formation.

In the bed of Bayou Castor, close by, there is a ledge of soft aluminous limestone, greatly resembling the "rotten" limestone of Mississippi, but void of fossils.

A few hundred yards northward of the lick, there is a dug well twenty feet deep, in which a similar rock was struck at five feet, which became harder as the depth increased, and had to be blasted. The rock now lying near the well is a rather hard crystalline limestone, full of debris of shells; a great many perfect ones were found in digging; one described to me must have been a *Janira!* No salt water was obtained in this well.

Another well was bored one hundred and thirty-six feet deep, and on penetrating the rock at this depth, salt water rose to within reach of a very crude suction pump—indicating a strong artesian rise. This well has chiefly furnished the brine for boiling, but is quite weak—not, I should think, above the strength of sea-water. Hence the manufacture of salt ceased with the war.

About a mile east of the works, in a boggy place, there were several detached blocks of white crystalline limestone, similar to that at the dug well. But whether these had been brought here or not, could not be ascertained.

From this interesting locality, the first one at which the existence of cretaceous outcrops in Louisiana was recognized, the party proceeded eastward to Rayburn's Salt Works, on Saline Bayou.

The country between is quite undulating and in part very sandy, so as to wash very badly. Oaks mingled with the short-leaved Pine form the timber to within seven miles west of Saline Bayou, where the long-leaved Pine sets in. At times the heavy red clay subsoil appears, and lignitic clays are found in wells; but the ridges are everywhere capped with the Drift materials, whose character, on the whole, predominates.

RAYBURN'S LICK.

On crossing the Saline, we ascend a high hill into the usual oak and pine country. Six miles from the crossing, on S. 34, T. 15, R. 5 W., there is an extensive flat like that at King's, covered with deserted pits and furnaces, built of ferruginous sandstone. As much as eighteen hundred bushels of salt per day have been made here during the war, and it is stated that a single well might have supplied all.

The variety of materials taken from these pits is very great. In the chief well, limestone like that at King's was found at twenty feet.

It being extremely difficult to ascertain positively the exact succession of strata in the present condition of the pits, I give the profile as obtained on the spot from Reuben Whitlow, an intelligent mulatto, who worked here during the war.

Profile of Salt Water Pits at Rayburn's.

NO.	MATERIALS.	FEET.
4	Whitish mud of the lick, with ferr. spots, and at base frequently bearing balls of pyrites	6
3	Siliceous gravel, often cemented into a conglomerate by crystallized calcite	6—7
2	Grayish or white crystalline limestone, horizontally banded, fragile, often covered with 5—6 inches crystallized aggregates of calcite, on a dark, banded base of the same	6
1	Dense, banded gypsum, pure	2

No. 1, the gypsum bed, was reached only in the pits of the S. E. side, and the salt water came up from beneath; in the other pits it came in through crevices in the limestone. The latter resembles that seen at King's, but appeared to be void of fossils; sometimes it is very porous and mostly in irregular lumps, exuding salt.

Some of the gypsum is beautifully banded, and is almost alabaster.

From Rayburn's Salt Works, now also deserted, the party proceeded to Brushy Valley, where valuable information was obtained from Dr. F. C. Gray, as well as from Mr. Wm. N. Parke.

LICKS AND PRAIRIE SPOTS.

It appears that, as a rule, lignitic clays and sometimes lignite, are struck in most of the wells in the region; but that isolated patches of calcareous materials are found at several points near; e. g., on Coulée Creek, a few miles above Dr. Gray's, and at or near Rochester, where the soil is a true black prairie, with calcareous concretions, but no shells so far as known to Dr. G., nor any indication of salt. He states, however, that shells were found abundantly at Rayburn's, as well as at King's.

Mr. Parke states that "prairie spots" exist also on Choctaw Bayou, about ten miles northward of Dr. Gray's; and on Antoine Bayou, near Louisville, Winn Co., as well as on Big Creek. Also, that ferruginized shells, such as were shown me by Dr. Gray at Lake Charles, occur on SS. 7 and 18, T. 15, R. 4 W., and SS. 12 and 13, T. 15, R 3 W. This soft shell rock is found a few feet beneath the surface, in digging wells; is underlaid by 20—25 feet of red, or red and white, clay, beneath which, after penetrating a thin layer of sand, lignitic clay or lignite is struck. These shells are therefore doubtless of tertiary age, and they as well as the "prairie spots" do not seem to be related to the cretaceous beds of the salt licks*

Unfortunately, there was no time for a personal examination of the localities referred to above; and the party proceeded southward to "Price's Lick" and Salt Works, on S. 25, T. 13, R. 5 W., or thereabouts. On this route, we pass from the undulating oak uplands with short-leaved pine, into the long-leaved pine woods, about five and a-half miles S. E. of Dr. Gray's, after crossing Brown's Creek. The

* This supposition has since been confirmed by the researches of Dr. F. V. Hopkins.

soil is mostly rather sandy, yet occasionally the red clay subsoil reappears. The dividing ridge itself only is absolutely poor, there being much good oak land on the slopes. The ferruginous sandstone of the Drift is not as abundant here as near Brushy Valley; where (just south of Dr. Gray's), there are outcropping ledges of some thickness. Available iron ore does not, however, seem to occur in the region.

PRICE'S LICK.

Price's Lick, which resembles the others in its general character, is of a horseshoe shape, about one-half mile across from edge to edge. On its eastern edge runs Cypress Bayou, a small but brisk stream. The whitish and rather sandy surface of the lick possesses a well pronounced saline flora, and exhibits an abundance of roundish, distorted calcareous concretions, some as much as eight ounces in weight.

The materials thrown from the pits are exclusively gray laminated clay ("soapstone"), of the usual character of the lignitic Tertiary. The pits are not very deep, and perhaps the underlying limestone and gypsum had not been reached in them. The brine was stronger here than at either King's or Rayburn's. As at the latter localities, the (now deserted) furnaces here are built of the ferruginous sandstone of the Drift, which occurs on the hills, though not as abundantly as near Brushy Valley.

Among the rubbish we found rounded concretions of a yellowish green, radially crystalline mineral, weathered on the outside into a pale yellow powder; doubtless Vivianite, somewhat altered.

DRAKE'S SALT WORKS.

From Price's the party next proceeded to Drake's old Salt Works, on Saline Bayou, then owned by Mr. J. C. Weeks. The licks extend for one and a-half miles along the bayou. At their northern end, on the east bank, a number of artesian wells have been bored; one, a thousand and eleven feet deep, and said to have been sunk in uniform limestone rock all the way, spouts a constant stream of from eighteen to twenty gallons of salt water per minute. It now runs out four and a half feet above ground, but will rise above thirty-five feet in pipes; the discharge is said to have decreased since first bored.

The water of this well contains two per cent. of solid matter, which consists, by subsequent analysis, of

Chlorid of Sodium	93.30
" " Magnesium	1.78
Carbonate and Sulphate of Lime	4.92
	100.00

There are seven other wells, all running when cleaned out, but of less depth, and having somewhat stronger brine than the first named. They were bored some thirty years ago for Mr. Drake, and their record is not known.

Here as elsewhere, many pits were dug during the war, fifteen to eighteen feet deep. All these struck the laminated clay or "soapstone;" but in the rubbish of one I found large fragments of a very crystalline, yellowish limestone, horizontally banded with gray; evidently the same as that at King's and Rayburn's.

The lick is overflowed at high water, and was partly so when seen by us. There is a splendid water power here, and a large saw and grist mill, as well as salt boiling, were carried on during part of the war; when the whole establishment was destroyed by fire.

Mr. Weeks states that a mile below this point there is an outcrop of red and gray rock on a hillside facing north. Also, that six miles farther west, a ledge of limestone crops out in the bed of a creek, and there is a cliff (also facing north) of fossiliferous limestone, of which lime has been made. Analyses of these limestones, which are doubtless of tertiary age, will be given below.

Near the northern edge of the lick, there is an alkaline sulphur spring, whose salts were used in lieu of soda, during the war, in cooking.

From Drake's the party proceeded, through unchanging, undulating, long-leaved pine forest, towards Winfield, near which place there was reported to be a "limestone cave."

THE LIMESTONE HILL NEAR WINFIELD.

The locality is on Mr. Matthews' place, S. 19, T. 11 N., R. 3 W. A pond about forty yards across, is surrounded by limestone hills and cliffs—real escarpments, fifty to sixty feet above the drainage of the country, and the rock but scantily covered with soil on which, among other plants not usually seen in this region, the red cedar is abundant.

The rock is clearly of the same character as that seen at the salines above; it is crystalline, horizontally banded; sometimes pure white and yellow calcite, crumbling like loaf sugar; but mostly grayish with darker stripes, and strikingly like the rock seen near Chicotville, in St. Landry Parish. Being very pure, the rock makes excellent lime; but seems to be totally void of fossils. Were it not too brittle, and full of fissures and pores, some portions of it would form a beautifully banded marble.

The "cave" is now a mere crevice in the face of a cliff, and would never have been formidable. There is also a "tower," an isolated limestone cliff, with almost perpendicular sides. It is evident that subsidences and consequent dislocations frequently occur in the mass; and large fragments frequently tumble down. There are a number of slightly mineral springs around; probably merely underdrains of the pond mentioned.

CEDAR LICK.

No other limestone outcrop is known to occur nearer than those at Drake's. But about seven miles south-east from this limestone hill, there is another salt lick, called Cedar Lick (from cedars growing

there); it is several acres in extent, and there is on it a steadily flowing brine spring, of pure taste and considerable strength. It can hardly be doubted that here, also, the cretaceous rock underlies at a moderate depth.

HOMEWARD BOUND.

Having now accomplished the round of the salines, the party was compelled, for want of time, to proceed with all possible dispatch towards Harrisonburg, and make such observations only as happened to be practicable under the circumstances; the route having been selected with a view to re-crossing the formations, knowing Harrisonburg to be located on the Grand Gulf rocks. No outcrops of the marine Tertiary, however, were found until the territory of the Vicksburg group was reached, which presented features altogether similar to those observed after crossing the Toreau, in Sabine Parish (see above).

For about seven miles south-east of Winfield, the long-leaved Pine continues to prevail on the dividing ridge (between Dugdemona and Bear Creek); Oaks mingled with short-leaved Pine occupy the slopes, while Beech, heretofore very abundant in the bottoms, almost disappears. Beyond the point mentioned, a growth of White Oak and Sweet Gum appears on the hills, with a heavy red subsoil—precisely as is the case between Sabinetown and the Toreau, just north of the Vicksburg rocks. But there was no time to search for outcrops. Subsequently, Prof. Hopkins has found in this region, as well as farther north, a number of patches of the lower marine Tertiary (of the Jackson age). We could only hear of lignitic clays.

RE-CROSSING THE VICKSBURG ROCKS.

Upon reaching the Natchitoches and Harrisonburg road, which we followed thereafter (about the middle of T. 10, R. 2 W.), there commences a level tract of country much resembling that above and around Black Lake and its bayous, described above; viz: Post Oak and Pine flats, with a "hog-wallow" soil of heavy gray clay. This feature becomes more pronounced as we advance eastward; and about seven miles (west) from Little River ferry, we find outcrops of whitish, heavy, concretionary clay marl with *Orbitoides Mantelli*, *Pecten Poulsoni* and *Ostrea Vicksburgensis*, the leading fossils of the Vicksburg group. Of this clay there are about five feet, and it is underlaid by a stratum of hard, concretionary limestone. Shortly after, we reach a prairie dotted with thickets of Crab Apple and Red Haw, which is about two miles long, north and south, by one and a-half mile east and west; a fine, but ill-drained soil.

Farther on, we find a dividing plateau covered with long-leaved Pine, skirting the bottoms of Dugdemona and Little River; which are timbered with Water Oak and other growth belonging to second rather than first bottoms; though traversed abundantly by Cypress sloughs.

We were informed that about eight miles below, just below the mouth of Fishing Creek, there is a bluff, about one hundred feet high above low water—the rock which forms it being so soft that people cut their names into it. This I presume to be Grand Gulf claystone.

CATAHOULA PARISH.

About two and a-half miles east of Gilmore's ferry we find on the slope of a hill, an outcrop of yellowish Vicksburg limestone; then on top of the hill, Grand Gulf sandstone, with underlying gray clays. This is the dividing ridge between Little River and Bayou Funne Louis, and the outcrops continue for a few miles; when, on descending the eastward slope, we again find outcrops of Vicksburg limestone. Thus each ridge appears to form a "nose" of Grand Gulf rocks projecting northward into the Vicksburg territory; as is so commonly the case in Mississippi. The higher ridges are frequently capped with a mamillary mass of the red sand and ferruginous sandstone of the Drift.

Hence to within six to eight miles of Harrisonburg, there is an abundance of outcrops of the Grand Gulf sand-and claystones, and associated clays, both on the hills and in the creeks; the long-leaved Pine being frequently of a stunted growth, where the latter very barren material forms the soil. Occasionally a strip of white oak land intervenes; and at the point mentioned, there commences a tract of yellow loam soil, at first very sandy, and timbered with long-leaved Pine, which in time is replaced by the short-leaved species, mingled with Oaks; the ridges being exceedingly sharp and narrow. Toward the north we occasionally catch a glimpse of the level prairie country of the Vicksburg group, lying at the foot of the Grand Gulf hills, and probably influencing the alternations observed in the vegetation of the lower ridges, and valleys.

Rock Creek, a branch of Burseley Creek which empties into Catahoula Lake, is crossed on ledges of Grand Gulf rock; and on the eastern bank there are extensive exposures of the white clays that overlie. Near the base is a twelve inch layer of strongly lignitic clay, with traces of vegetable impressions—the first instance of the kind seen by me in Louisiana, where this formation appears to be even more hopelessly barren of fossils than is the case in Mississippi.

As we approach Harrisonburg, the Drift on the hills becomes more and more pebbly, and the last slope, about three miles from town, is completely covered with shingle of the usual character, as seen opposite, on the Mississippi bluff.

HARRISONBURG.

Outcrops of sand and claystones still continue up to the town itself, which lies on a terrace above the level of high water, on the bank of the Washita; and at the foot of a hill whose slopes are white with outcrops of the clays, claystones, and sandstones of the Grand

Gulf age. The subjoined section* was observed by Dr. Walker, after we parted company.

Profile at Harrisonburg.

NO.	MATERIALS.	FEET.
11	Drift sand with much shingle	10—20
10	Sandstone with yellow streaks, soft	1½
9	Bluish siliceous clay	3
8	White, fine-grained, sharp sandstone	3—6
7	Clayey sand, with irregular masses of sandstone	10
6	Hard gray sandstone, cherty	4
5	Brown sandy clay	6
4	Greenish sandy clay	3
3	Sand and clay, laminated	3
2	Loose sandstone, or semi-indurate sand	4
1	Lignitic clay	?
	Talus, still above the town level	?

SICILY ISLAND; THE LOESS.

The last exploit of the party was an examination of the southern part of Sicily Island, under difficulties; the first being to paddle up the river, which was high, in a canoe manned chiefly by raw hands. This examination was of especial interest to me, on account of specimens of limestone having been collected there by Messrs. Halliday and Coningsworth, fellows of the New Orleans Academy; and in this rock I hoped to find the thus far vainly sought fauna of the Grand Gulf group.

Sicily Island (which is cut off from the mainland by the Washita, and from the bottom by Deer Creek and bayous Maçon and Louis) is in part quite hilly; like the mainland opposite, its hills are formed by Grand Gulf rocks, mainly a rather soft, tawny sandstone, which crops out on all the ridges. At one point, not far from Mr. Kendrick's place, a cut in the hillside reveals a stratum of bluish calcareous clay, the counterpart of that forming the Anacoco prairie soil, and likewise occurring at Grand Gulf and on Pearl river, in Mississippi. An analysis of this marl will be found below; it has doubtless contributed towards rendering the talus of these hills so remarkably fertile; but shows no trace of limestone.

After a long search, we finally succeeded in finding the rock sought for, and were severely disappointed. Perched on a terrace of the common Grand Gulf sandstone, and forming the summit of a high hill, was a knoll about eighteen feet high, whose lowest portion showed Drift gravel and sand, while the uppermost five or six feet consisted of gray silt containing gnarled, hard concretions of carbonate of lime, often cellular, and (very rarely) containing casts of *Helices*. Similar knolls

* The details of this section do not agree very closely with those given by Hopkins; probably both are correct, but taken at different points of the ridge. Such discrepancies within short distances are very common in the Grand Gulf group.

exist at other points in the island, always capping the highest summits; they are obviously outliers, or rather, remnants of the Bluff or Loess formation, whose main body has doubtless been cut away by the mighty ancestor of the Mississippi, during the last period of elevation; leaving on the eastern bank, however, a strip of about fifteen miles average width—to-wit: the "Cane Hills" of Mississippi and East Louisiana.

Although without any bearing on the problem which it had been my special desire to elucidate, viz: that of the precise place of the Grand Gulf rocks in the tertiary series: these outliers are of considerable interest, because they show unequivocally the hypsometrical relation existing between the Loess and the older deposits occupying the level portion of Sicily Island, and the Tensas bottom.

Returning about midnight to Harrisonburg, the party next day broke up, after a ride of nearly six hundred miles, in the course of twenty-seven days. Leaving my companions to take a boat at Harrisonburg for New Orleans, I myself traversed the bottom on horseback, to Waterproof on the Mississippi, whence I took a boat to Vicksburg.

THE TENSAS BOTTOM.

My route lay across Sicily Island, partly over the neighborhood explored the day before. Crossing the Washita and Bayou Louis, the road passes through the hilly portion of Sicily Island for about five miles, then turns off south-eastward into a level country, not at all swampy, above high water, and possessing rather the character of a hommock or second bottom. The soil is excellent, the subsoil a brown loam; and on the shore of Lake Louis, there is a bluff some twenty feet high, washed into cliffs like the indurate yellow silts of the Port Hudson bluff, which it greatly resembles and to which, probably, it corresponds geologically.* Large cotton plantations cover almost the whole of this region.

The waters of Lake Louis covered the low bottom lying opposite, to the depth of several feet; and it was with some difficulty that, with the aid of the blind ferryman at Mr. W. S. Peck's ferry, I succeeded in reaching dry ground, and the magnificent plantations on Tiger Bayou, through which I made my way to Kirk's ferry, on the Tensas.

The soil here, of the "buckshot" character, is very much like the "bottom prairie" of Red river; it frequently contains calcareous concretions; and its natural vegetation (Honey Locust, Crab Apple, Plum, etc.), is of the prairie character. At several points in the bayous, and on the Tensas river itself, it reaches to the water's edge with little change, being, of course, totally distinct from the modern river deposits, and too uniform and widely spread to be ascribed to any modern cypress swamps. It is, doubtless, the counterpart of the lower portion of the Port Hudson Bluff.†

* Am. J. Sci., Jan., 1869, p. 79; strata Nos. 3 † and 5. Ibid., Oct., 1872, p. 268 and ff. Smiths. Contr. Knowl., 248, p. 23.

† Ibid.

Having, with considerable difficulty, crossed the Tensas after sunset, the rest of my ride along Choctaw Bayou to Mr. Jno. F. Goodrich's, was by moonlight, and observations not in order.

On the following morning I reached Waterproof at 10 A. M., my observations on the route having only served to confirm those of yesterday regarding the profuse fertility of the Tensas country, and the non-alluvial origin of its best soils.

I found "Waterproof" to have proved untrue to its name, and to be fast retiring behind the levee. And here terminated my personal observations.

NORTH CATAHOULA.

In the meantime, Dr. Walker made use of two days during which he should have to wait for a boat, for a supplementary reconnoisance up the river from Harrisonburg, in accordance with my request, with a view to the determination of the northern limit of the Grand Gulf rocks. I give his observations in his own words:

"*June 19th.*—Started up the Columbia road, finding frequent outcrops of Grand Gulf sandstone. A short distance beyond the twelve mile post (which it seemed to me, considering the crookedness of the road, should have been more nearly the twentieth), I found in a branch bottom an outcrop of loose sandstone underlaid by fifteen to twenty-six inches of lignitic clay. Concluding that I must be near the limestone, I observed closely for the next two miles, when I found an outcrop crossing the road; it was yellow concretionary limestone, such as that seen on Bayou Funne Louis. A hundred yards farther on was an outcrop of blue fossiliferous limestone. Stopped for the night.

20th.—Went on two miles farther (i. e., to sixteen miles) with Mr Harrellson, who showed me more limestone outcrops, of which I took specimens. The first are about ten feet above the bed of Sugar Creek (so called from Sugar Maple growing on its banks), and the last were near the top of a hill, as we went on.

We then turned southwest, striking the creek two miles above, but at a level not much different from that near the first outcrops. Here I saw a bed of lignite, of which two feet were visible in the bed of the creek, and disappearing under water.

Half a mile farther south, on top of a high hill, I found the Grand Gulf sandstone. Two miles to southward of this locality are the "Chalk Hills," of which we had repeatedly heard heretofore.

The first outcrop exhibited a stratum of grayish, compact claystone, turning white by exposure; it lies on top of a high hill, beneath eight to ten feet of loose white sand with concretionary ferruginous gravel; it was underlaid by ten to twelve feet of common, coarser claystone. Farther southwest, this "chalk" appeared lower in each successive outcrop, and overlaid by sandstone resembling No. 4 of the Harrisonburg profile; and finally disappeared.

The day being far spent, I set out on my return, reaching Harrisonburg just before nightfall. Got everything ready for the boat, which came along at daylight on the 21st; so that I reached home safely on the 22d."

Dr. Walker's observations fixed most satisfactorily the northern limit of the Grand Gulf rocks, showing the phenomena on the Washita to be substantially the same as on the Toreau and Funne Louis; and also, that the ridge of Grand Gulf rocks, at whose northern foot lie the Vicksburg prairies, traverses the State from the Washita to the Sabine, forming the prominent topographical feature of Northern Louisiana.

The "chalk," which does *not* make a mark on a board, is simply a pure siliceous claystone, as shown by a qualitative analysis made by Mr. Loughridge.

LIGNITES.

As regards the lignite, I subjoin the determinations of ash (made by the same), both of the Sugar Creek lignite, and that from Granning's Ferry on the Bayou Pierre.

Ash Determinations of Lignites.

Sugar Creek, Catahoula Parish	15.12 per cent.
Granning's Ferry, DeSoto Parish	10.63 " "

These are about average percentages, and if the beds are sufficiently extensive, they will doubtless prove valuable.

The clay marl of the Grand Gulf age, occurring near Hendricks' house on Sicily Island (see above) showed the following composition:

Clay, etc	94.19
Carbonate of Lime	5.81
	100.00

Similar materials occurring in Mississippi contain from 0.7 to 1.2 per cent. of potash. But the large amount of inert matter would render their use at any great distance from the point of occurrence too expensive. The marl forming the soil of the Anacoco prairie, is doubtless of a similar composition.

So far as at present known, the marls of Louisiana are far inferior both in quality, quantity, and variety, to those of Mississippi; yet even thus they will doubtless serve important uses in soil improvement.

RECAPITULATION.

The general results of the expedition having already received mention and discussion in a previous publication, I shall only recapitulate them in so far as they are not sufficiently set forth in the preceding record, or have received additional light from subsequent researches.

I premise that the direction of my researches in Louisiana was measurably governed by the probable supposition, that the geological conformation of Louisiana, lying west of the main axis of the Mississippi valley, must be more or less accurately the reflected image of that of the States of Mississippi and Alabama, east of the same.

The route was, therefore, so chosen as to cross the trend of the formations as often as possible.

This leading supposition was, on the whole, fully verified, with such modifications as the difference of geographical position with reference to the continental interior might have lead to anticipate. Two special problems, however, to which analogy could furnish no clue, presented themselves at the outset, viz: that of the age of the salt deposit of Petite Anse, and that of the great sulphur bed of Calcasieu. The former I had found it impossible to solve by an examination of Petite Anse and its sister islands;* while the interpretation of the strata penetrated in the Calcasieu bores, was equally precarious, unless based upon an investigation of the formations of the interior. At the same time, these data were invaluable as starting points for comparison. As such, I insert here, once more, the Calcasieu profiles, as obtained by me on the spot, from the statements of the well-borer (Mr. Munn), and verified as well as rectified by comparison with the pile of borings at the mouth of the wells.

Profile of Artesian Wells, West Fork of Calcasieu river.

KIRKMAN'S WELL.			LOUISIANA OIL CO.'S WELL.			Formations
Depth	Thickness.	Materials.	Depth	Thickness.	Materials.	
Feet.	Feet.	Blue and yellow clay, with some sand strata.	Feet.	Feet.	Blue clay, sometimes with layers of sand soaked with petroleum.	Port Hudson Group.
	354		160	160		
			333	173	Loose sand and gravel, 138 to 153 ft. very pebbly; 153 to 173 ft. finer material.	Orange Sand Group.
			343	10	Gray laminated clay ("soapstone").	Vicksburg Group.
	96	Sand with clay laminæ, 36 feet. Sand and gravel, 56 ft.	383	40	Blue, sandy, nodular limestone, with marine shells, petroleum and gas.	
450		Sandy pipeclay, 4 feet.	443	60	Soft, white, crystalline, crumbling limestone; tube driven through.	Cretaceous Formation.
			543	100	Pure crystalline sulphur.	
			690	147	Sulphur and gypsum, alternating. About ½ sulphur. 5 ft. sulphur bed at 650 ft. 10–15 " " 680 "	
				540	Pure gypsum. Dense, granular, and coarsely crystalline, grayish or white	

* Am. J. Science, Jan., 1869, p. 83.

The general correctness of the second profile has been confirmed by additional borings made since, by the Calcasieu Sulphur Mining Co., the only material difference reported by Mr. Granet being the fact that the sulphur is always mixed with a variable but small proportion of limestone or carbonate of lime, which makes it probable that some of the rock strata found alternating with the sulphur beneath the great sulphur beds may also be limestone, instead of gypsum or plaster rock.

As regards the higher strata, the only difference noticed was the absence of the "soapstone" or laminated clay stratum—not a matter of surprise in a locality in which, as the above profiles show, there had been extensive denudations before the deposition of the quaternary strata began. My conjecture that the petroleum originated exclusively in the nodular limestone stratum, and that no more of it was found after reaching the white crystalline limestone, was also confirmed by the new bore.

My interpretation of the formations as given in the above diagram, has but received additional confirmation from later researches, both of Prof. Hopkins and myself; except only in so far as the nodular limestone at Sabinetown, which I identified with the petroleum-bearing rock of Calcasieu, and conjectured to belong to the Vicksburg group of the Tertiary, has since been shown by Hopkins to belong to the Jackson group of the same formation.

Of the identity of the Drift or Orange Sand, and the Port Hudson group, respectively, there can be no reasonable doubt.

My conclusions were based, first, upon the known southward dip of the formations in Mississippi and Louisiana, which would cause those found far below the surface near the coast, to crop out in the northern part of the State. Secondly, upon lithological resemblance. Thirdly, upon reasoning by exclusion.

The southward dip had not, it is true, been directly observed; but the general conformation of the Mexican Gulf border admits of no other arrangement, aside from local disturbances.

As to lithological resemblance, it would not be a cogent argument where a great diversity of formations might be suspected. But this was not the case here; and I had, moreover, assured myself of the remarkable uniformity with which the general character of the several subdivisions of the cretaceous and tertiary formations are maintained over large areas. The Vicksburg limestones and the Grand Gulf clays of the Sabine were undistinguishable from those of the Chicasawhay and Pascagoula, respectively. There was, therefore, good reason to expect that the rocks penetrated in the Calcasieu bores, would be identifiable at their outcrops farther north, even without the aid of fossils—none in a recognizable condition having been brought up by the augur.

The two limestones of the Calcasieu well differ widely from one another. The nodular, petroleum-bearing, sandy rock calls to mind at once the "nigger-heads" of the Mississippi Tertiary, with its lignito-asphaltic affinities; while the white, crystalline, brittle limestone beneath has no analogue in the Tertiary, but recalls the uppermost

crystalline limestone of the Ripley group of the Cretaceous in North Mississippi. The great gypsum bed of Calcasieu could not fail to suggest some connection with the great gypsum formation of the upper Red river; and likewise admonished one at once of the usual and almost necessary correlation between gypsum and rock salt, whereof an unusually large and pure mass appeared on the same coast, at Petite Anse. Such were the ideas suggested to me by a consideration of the Calcasieu profiles.

The rocks of the Grand Gulf age should have appeared in these profiles directly beneath the Drift materials. But nothing had been found resembling them in the least; and since of all the tertiary groups, this one is the most persistently uniform in its lithological character, its absence might be taken as proven—it having, doubtless, been removed through the agency of the drift currents.

The Vicksburg rocks would come next; and to some of these the nodular limestone of Calcasieu bears considerable resemblance; while in Mississippi at least, the Jackson group exhibits no corresponding materials. But on reaching the Vicksburg rocks after crossing the Toreau on the way to Sabinetown (see above), I found them to be altogether unlike the Calcasieu rock, while exactly like the Vicksburg limestone on the Alabama line. At Sabinetown, however, the exact counterpart of the petroleum-bearing, sandy, nodular limestone of Calcasieu, traversed by veins of calcareous spar, was exhibited in the bluffs; and in the apparent absence of characteristic fossils of either group, and the utter dissimilarity from the Jackson rocks of Mississippi, I thought it most probable that these rocks also, represented the Vicksburg age. That this was proved to be erroneous by Prof. Hopkins, I have already stated. The fossils collected by him show that not only the Sabinetown bluff, but the whole of the Tertiary of North Louisiana, at best up to within twenty miles from the Arkansas line, are the equivalents of the Jackson strata of Mississippi; that throughout the lignitic area passed over by me, there exist outliers of marine limestone with Jackson fossils; and that ancient beaches of such rocks seem, as a rule, to occur near the salines of North Louisiana. Not having, himself, found any cretaceous fossils at the latter localities, he was inclined to consider these, themselves, as originating in the tertiary strata.

He, of course, yielded to the palaeontological evidence I had to present in the shape of cretaceous fossils from Rayburn's Lick, as I did to that he brought from Sabinetown. But, in order to show, as conclusively as possible, the lithological correspondence of the rocks from the several localities, I have had recourse to chemical and microscopic analysis, which has fully borne out my views, so far as it goes.

I give below the comparative analysis of tertiary and cretaceous limestones made by Mr. Loughridge; remarking that Nos. 3 and 4, which I had not examined in loco, were by me supposed to be of cretaceous age, and so laid down on my first geological map of Louisiana, presented before the American Association for the Advancement of Science, at Chicago, in August, 1869. But an examination of

capable of furnishing an inexhaustible supply of this material, and adapted to all the uses of which it is capable.

I trust that the great shaft now being sunk on the site of the first bore in Calcasieu, will complete the data necessary to establish beyond cavil, the important practical conclusions foreshadowed above.

REPORT

ON THE

GEOLOGICAL AGE OF THE MISSISSIPPI DELTA

BY

PROFESSOR E. W. HILGARD

TO

GENERAL A. A. HUMPHREYS.

WASHINGTON.
GOVERNMENT PRINTING OFFICE.
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PROFESSOR E. W. HILGARD.

OCTOBER, 1870.

DEAR SIR: I have the honor to submit to you herewith a detailed report and discussion of my examination of specimens from the New Orleans artesian well of 1856, which you in 1866 referred to me for the purpose of determining the geological age of the deposits penetrated.

The occasion which gave rise to this investigation was, as you will remember, a suggestion to you on the part of Sir Charles Lyell that the statement made in your "Report on the Mississippi River," p. 99, viz: "that the river is flowing through it [the delta region] in a channel belonging to a geological epoch antecedent to the present," should be subjected to the test of a comparison, by some competent observer, of the shells collected in sinking the artesian well at New Orleans, with those of the cretaceous and tertiary on the one hand, and those now inhabiting the Gulf of Mexico on the other. Mr. Lyell was inclined to think that the strata pierced at New Orleans, and forming the bed of the river at Bonnet Carré, might themselves be interpreted as belonging to the delta formation, since, judging from the profile given by the committee of the New Orleans Academy of Sciences, marine and fresh water strata might seem to be alternating in such a manner as to admit of that interpretation.

You ascertained, however, upon inquiry, that unfortunately the suite of specimens collected by the academy committee had been much broken and dilapidated during the war, while the gentleman who had been chiefly active in the matter, Dr. N. B. Benedict, then secretary of the academy, had since died. Nevertheless, a suite as complete as possible was made up, at your request, partly from the specimens remaining at the academy, partly from another suite collected by Dr. J. L. Riddell, (deceased,) and sampled for the purpose by his son, Dr. S. S. Riddell. A suite of fifty-one specimens, thus made up, was placed by you in my hands, together with specimens of soundings, &c., collected by the delta survey, under your charge, which had been previously examined, for the greater part, by Mr. L. S. Pourtales. Of the interesting report made to you by the latter gentleman, of the results of his microscopic examination of these specimens, a copy was also furnished me.

The general result of the preliminary examination made by myself immediately upon receipt of the collection is already known to you, and is given in the first volume of Sir Charles Lyell's "Principles of Geology," 10th edition, p. 459. Since then, I have not only made a full examination of the entire suite, but, as my knowledge of the general geology of the Gulf coast progressed, I have reviewed and repeated my previous work in many respects. The investigation was beset with many difficulties, not apparent at first sight. Not the least among these was the condition of the specimens, many of which had doubtless been exposed *to dust, insects, &c.,* for years. This greatly increased the difficulties of

the microscopic investigation, especially since, in specimens which are mostly pulverulent, it was not only the remains of marine or fluviatile faunas and floras, but also all the infinite variety of objects which may result from the visits of roaches, spiders, "candle bugs," ichneumon wasps, flies, and the vegetable hairs, pollen, spores, &c., which may blow in through open windows, that had to be distinguished and eliminated. I have, for this reason, confined the detailed microscopic examination chiefly to critical specimens, and such as, being in lumps, offered some security against accidental contamination of the kind alluded to.

Other cases of doubt have arisen from the presence of a few large shell fragments in specimens which, otherwise, showed no evidence of marine origin, making it probable that these fragments were accidentally introduced either in the collection room or, perhaps, in the bore itself, where the shells of higher strata may easily adhere to some pasty borings while being drawn up in the auger.

The latter cause may also in a slight degree vitiate the mollusk fauna of lower strata. But the cause of the trouble and uncertainty regarding the debris of animalculæ, above referred to, does not with any degree of probability apply to the mollusks, unless we imagine the specimens to have been accidentally or wilfully commingled, which, so far as I am aware, there is no reason to suppose.

I have, therefore, not usually pursued the microscopic examination into detail where strata were well characterized by shells visible to the naked eye. The latter, of course, were frequently the larger species, always represented by fragments only, and the proper reference of the latter was, in numerous cases, a matter of no slight difficulty, and sometimes dependent upon a happy inspiration, not always at command. I have, in most cases, when any doubt could remain as to the specific reference of a fragment, verified the result by a comparison of microscopic characteristics with those of living species in the conchological collection of the University of Mississippi, (the Budd cabinet of shells,) or specimens collected by myself on the Gulf coast.

Unfortunately the minute surface markings, which in such cases may serve to identify species, are most frequently obliterated in those strata in which shells are usually most abundant, viz., those of beach sand.

The species named in the following record, and on the subjoined general profile, are, of course, only those of which the identity could be established at least with a degree of probability amounting almost to a certainty. There are among the debris, not identified, probably from 20 to 25 species which, while not identical with any of those mentioned, are yet too imperfectly represented to be positively identified with others, or, perhaps, to be reconstructed from such slender premises save by the aid of some lucky accident or inspiration indicating the proper direction.

The most hopeful field for additional identification lies, perhaps, among the large number of young shells which occurs at some points. Our knowledge of the development of most of the mollusks of our southern coast is too imperfect to serve for the identification of the species in a very infantile condition—in fact, as Mr. Conrad has remarked in a letter to me on the subject, the mollusk fauna of the Gulf is as yet, in a great measure, a *terra incognita*, and when we find, in littoral strata of no very ancient date, fossil shells not as yet described, it cannot with any degree of certainty be said that they may not yet be living on the waters off the Louisiana coast. The shells of Florida and the Antilles *are comparatively well* known, because readily accessible. But the mud *ts of the Louisiana* coast, apart from being rather an unpleasant

trysting-ground, do not offer to the amateur collector those brilliant inducements which, while in the main conducive chiefly to parlor ornamentation, yet collaterally bring about very frequently the discovery of species heretofore overlooked by professional naturalists.

So far from considering the subject in hand exhausted, I intend to pursue it further to the utmost extent of my ability, aided, as I hope, by additional borings into the strata of which a minute speck only has furnished the material for the present investigation.

Record of the examination of specimens of borings from the New Orleans artesian wells.

[The numbers of the specimens here given are independent of those of the strata in the profile.]

No. 1.—2 to 17 feet.—Buff and mouse-colored clayey silt, coherent, containing half-decayed rootlets and fibers, and ferruginous spots. Under the microscope it exhibits chiefly grains of clear quartz, mostly rounded, small. A few black grains, some mica.

No. 1^1.—17 feet.—Woody stems, somewhat softened, of a shrub, or hard herbaceous plant.

No. 2.—Bottom of stratum, 2 to 17 feet.—Same as No. 1, but with more ferruginous concretions, yellow, scaly, or concentric.

No. 2^2.—17 to 20 feet 10 inches.—Dark-colored, stiff clay, with some sand, and decayed rootlets, bark, &c. Dark-colored, rounded, hard ferruginous concretions.

No. 3.—20 feet 10 inches to 31 feet.—Gray silt, somewhat coherent; shows glistening points; under microscope shows pellucid quartz grains, rounded and angular in about equal proportions; a few dark grains, and little mica; no organisms.

No. 4.—31 to 38 feet.—Gray sandy clay, coherent, with many irridescent surfaces, some evidently casts of shells, while others seem to have been formed on the sides of the vessels, it being stated to have been of the consistency of porridge when extracted; contains some plates of mica and large rounded grains of white quartz; effervescent; no definite forms under microscope.

No. 5.—38 to 41 feet.—Gray sandy clay, as above; contains abundant spiculæ of sponges, acicular, ends bifurcate; arcuato-acicular and oblong stellate. With it two fragments of *Venus mercenaria*, perhaps accidental.

No. 6.—41 feet to 41 feet eight inches.—Chiefly coarse siliceous sand, part sharp, part rounded, mixed with a few fragments of shells, and grains of a black mineral, apparently tourmaline. Upon washing it yielded turbid water, which, under the microscope, showed fine sand and numerous small bodies of yellowish tint and pointed egg-shape, sometimes agglomerated into groups, not soluble in hydrochloric acid. *Cocconeis?*

No. 7.—41 (42?) feet.—Coarse rounded sand, with numerous shells, mostly broken, quite hard *Mactra lateralis*, *M. Sayi*; *Arca transversa*, *Cardium magnum*, *Tellina flexuosa*, *T. tenta*, *Lucina costata*, *Venus cribraria*, *Astarte lunulata*, *Pandora trilineata*, *Oliva literata*, *Natica pusilla*, *N. campeachensis*, *Acus dislocatum*, *Marginella limatula*, *Bullina cassaliculata*.

No. 8.—43 to 56 feet.—Quartzose sand, finer than No. 6, with more numerous black (sometimes triangularly prismatic) grains (tourmaline?) and debris of small shells, *Arca transversa*, *Tellina flexuosa*, *Mactra lateralis*, *Cardium n. sp.*, (235 feet,) *Balanus*, fragments of *Echinoids* and crabs. No very definite *Foraminifera* in the washings, (a Coscinodiscus?) and spicules. Sand grains, part sharp, part rounded.

No. 9.—56 to 66 feet.—Bluish-gray, fine marly sand; microscope shows many fragments of minute organisms; *Naricula*, *Actinoptychus*, and others. Many irridescent casts; great abundance of *Mactra lateralis*; *Cardium magnum*, *Tellina flexuosa*, *Natica campeachensis*. Sand grains part sharp, part rounded, with grains of green mineral, and some spicules.

No. 10.—66 to 69 feet.—Gray sand, pretty coarse, sharp, somewhat coherent, with *Mactra lateralis*, *Arca transversa*, *A. pexata*, *A. americana*, *Tellina flexuosa*, *T. alternata*, *Pholas costata*.

No. 11.—70 feet.—Coarse white beach sand, grains rounded, with a few debris of shells.

No. 12.—75 feet.—Sand similar to preceding, a little finer, with *Arca transversa*, *A. pexata*, *Venus cancellata*, *Anomia ephippium*, *Donax variabilis*, *Oliva mutica*, *Buccinum acutum*, *Balanus*.

No. 13.—80 feet.—Quartz sand of greenish tint, with black grains intermixed, like No. 8, but coarser, and with numerous fragments of infant shells, *Pholas*, *Arca*, *Mactra*, *Cardium*.

No. 14.—82½ feet.—Tough, greenish-gray clay, cutting very smoothly, with but little sand; some fragments of shells, *Arca transversa*, *Venus*, *Balanus*.

No. 15.—85 feet.—Sand similar to No. 8, but more greenish, and fewer fragments of shells, and some mica. Grains mostly rounded. A few spicules.

No. 16.—88 feet.—A piece of semilignitized wood. Gray, sandy clay, with white concretions of carbonate of lime. Sharp sand, but no *Foraminifera*.

No. 17.—89 feet.—Sand similar to No. 15, but no fragments of shells, or definite animalcules.

No. 18.—90 feet.—Yellowish-white or gray fine calcareous silt, somewhat coherent, strongly effervescent. Contains about one-third by bulk of fine siliceous sand, some fine mica scales, no shells or animalcules.

No. 19.—91 feet.—Sand like No. 15, with one fragment of a shell, (accidental?) No signs of animalcules. Quartz grains, mostly sharp, mixed with some yellow and black grains. Some scales of mica.

No. 20.—95 feet.—Fine gray sand or silt, slightly coherent and effervescent. Under microscope shows mostly sharp, transparent quartz grains mixed with yellow grains and green plates of mica, also transparent; a few black grains. A single straight spicule of doubtful character. Reëxamination, twice repeated, and with higher power, shows nothing more.

No. 21.—98 feet.—Greenish and yellow clay, slightly effervescent; contains some sand, no *Foraminifera*.

No. 22.—99 feet.—Fine greenish gray sand or silt, much like No. 20; effervescent. No animalculæ found. Washed to remove clay, leaves chiefly sharp quartzose sand with numerous mica scales; some black grains, mostly well rounded. One small quartz prism, and one of a green mineral, possibly a mica scale. No definite organisms.

No. 23.—104 feet.—Fine sandy mass, or silt, brownish-gray, like No. 18 in coherence and feel; more clayey than the preceding. Upon washing shows under microscope numerous scales of mica, also black and yellow grains, the former rounded, the quartz ores sharp.

No. 24.—109 feet.—Fine sand, greenish-drab, glistening with mica scales. Coarser than No. 22, which it otherwise resembles. Small fragments of shells, not recognizable; a striated piece of mother-of-pearl, hard. Decidedly of marine origin.

(Here occurs the first serious gap; no specimen of the 34-foot clay stratum, No. 26 of profile in Humphreys' report.)

No. 25.—146 feet.—Sand, clay, and shells, *Arca transversa*, *Anomia ephippium*, *Pecten dendatus*, (Sow?) *Pecten sp. Gnathodon cuneatus.*

(No specimens of Nos. 28, 29, and 30, of Humphreys' report.)

No. 26.—153 feet.—Cypress bark.

No. 27.—170 to 175 feet.—Concretionary lumps of fine ferrugino-micaceous sand, cemented by lime, effervescent. No animalculæ found, under microscope, but microscopic rhombohedra of calcic carbonate.

No. 28.—195 feet.—Fine greenish-gray, clayey, micaceous sand, effervescent; grains mostly sharp.

(No specimen of clay, No. 42 of Humphreys' report.)

No. 29.—230 feet.—Sand like No. 28, with fragments of shells; *Arca transversa*, *Mactra lateralis.* No *Foraminifera* found.

No. 30.—235 feet.—Coarse sand with *Arca transversa*, *Mactra lateralis*, *Tellina flexuosa*, *T. tenera*, *Venus cribraria*, *Semele*, (*cancellato-lamellate*,) *n. sp.*, CON. *Cardium n. sp.*, CON., (allied to *C. graniferum*,) *Abra. n. sp.*, CON., (same as at 41 feet,) *Pecten dislocatum*, *Pecten sp.* (same as at 146 feet,) *Fasceolaria distans*, *Buccinum* (*Nassa*) *acutum*, *Acus dislocatum.*

No. 31.—241 feet.—Coarse quartzose sand with little mica and numerous black grains, which are fragments, part sharp, part rounded, of brown iron ore, or a conglomerate of sand grains and the ore. *Mactra lateralis*, *Arca transversa*, *Tellina*, bits of wood, sand grains, much rounded.

No. 32.—246 feet.—Quartzose sand, finer than the preceding, coherent, non-effervescent, micaceous, greenish-gray. No small fragments of shells; one large one of *Arca ponderosa*, perhaps accidental. No *foraminifera* or *diatoms.* (No specimens of the clay struck at 252 feet.)

No. 33.—293 feet.—Pretty fine, uniform greenish sand, somewhat coherent, not effervescent. Small fragments and iridescent impressions of shells.

No. 34.—302 feet (?)—Greenish clay, very meagre. Is marked as above, but probably corresponds to the clay at 322 feet.

No. 35.—340 feet.—Dark gray or mouse-colored, fine, sandy material, somewhat clayey, effervescent; under microscope, quartzose sand with a few dark grains, almost all sharp. With a 500-power nothing more is seen, save a few dark spherical bodies with indefinite light spots.

No. 36.—370 feet.—Loose, pure sand, chiefly clear quartz, some amethyst, rose, yellow, green, and opaque red quartz; a few black opaque grains. All very much rounded, evidently beach sand.

No. 37.—377 feet.—Same as above, but coarser, with shells and fragments much worn. *Astarte lunulata*, *Arca transversa*, (*A. ponderosa?*)

No. 38.—402 feet 3 inches.—Sand same as last, but less pure. *Mactra lateralis*, *Arca transversa*, *Venus sp.* Contains granules of sand cemented by a ferruginous cement.

No. 39.—413 feet.—Sand like No. 37, with *Tapes n. sp.*, CON, *Mactra lateralis.*

No. 40.—420 feet.—Same as last. *Acus dislocatum.*

No. 41.—430 feet.—Fine greenish sand, no shells, under microscope, grains much rounded, with lumps of ferrug. conglomerate. Some linear spicules; no other organic forms.

No. 42.—440 feet.—Greenish sand, somewhat coarser than the preceding, much rounded, no shells; some mica and black grains.

No. 43.—450 feet.—Same as the preceding.

No. 44.—463 feet.—Same as preceding, with small bits of wood, more probably recent than fossil.

No. 45.—476 feet.—Same, with small fragments of shells. *Venus cancellata, Mactra lateralis, Tellina.*

No. 46.—475 feet.—A rounded, ferruginous, concretionary pebble, studded with *Turbinolia* and shell fragments.

No. 47.—480 feet.—Coarse rounded sand with shells. *Gnathodon cuneatus, Venus paphia, Arca transversa, A. ponderosa, Pecten dislocatum, Ostrea sp.* (resembling O. ———,) *Anomia ephippium.* (No specimen of the 63½-foot clay stratum.)

No. 48.—544 feet.—Fine dark greenish, clayey sand, coherent, not effervescent, with fragments and impressions of shells much decayed and mostly irrecognizable, (*Arca pexata?*) *Anomia ephippium, Lucina costata, Bullina canaliculata.*

No. 49.—Between 543½ and 546 feet.—Coarse white beach sand, with numerous shells. *Mactra lateralis, Arca transversa, A. ponderosa, Lucina costata, L. multilineata, Pholas costata, Artemis concentrica, Cardium n. sp.*, (same as at 43 to 56, and 235 feet.) *Bullina canaliculata, Oliva mutica, Pleurotoma cerinum, Buccinum acutum, Natica pusilla, Dentalium sp.*

No. 50.—570 feet.—Tough brown clay, inclosing fragments of shells. *Astarte lunulata, Arca transversa, Tapes n. sp.* CON.

No. 51.—630 feet.—Gray gritty clay, micaceous; no shells. *Foraminifera* rather abundant. (Pourtales.)

In order that the paleontological evidence furnished by the preceding record and profile may be more readily appreciated, I have tabulated the result, so as to show at a glance the fauna of each of the principal shell-bearing horizons, as well as the vertical range of each of the species determined. For comparison I have also placed alongside, columns showing the occurrence of these species in the waters of the Gulf of Mexico, and in the strata described as post-pleiocene and pleiocene by Tuomey and Holmes, which occur on the Carolina coast.

Table showing the distribution of species.

	NEW ORLEANS ARTESIAN WELL.								Gulf of Mexico.	SOUTH CAROLINA.	
	41 feet.	66 feet.	76 feet.	146 feet.	235 feet.	480 feet.	546 feet.	570 feet.		Post-pleiocene.	Pleiocene.
Pholas costata	F.	F.			F.		F.		F.	F.	F.
Mactra lateralis	F.	F.			F.		F.		F.		
Mactra Sayi	F.								F.		
Gnathodon cuneatus				F.		F.			F.	F.	F.
Abra, n. sp. Con	F.				F.						
Tellina flexuosa	F.	F.			F.				F.	F.	F.
Tellina alternata		F.							F.	F.	F.
Tellina tenera					F.			F.	F.		
Tellina tenta	F.								F.	F.	
Donax variabilis	F.		F.						F.	F.	F.
Pandora trilineata	F.								F.	F.	F.
Venus cancellata			F.							F.	F.
Venus paphia						F.				F.	F.
Venus cribraria	F.				F.				F.	F.	F.
Venus mercenaria	F.								F.	F.	F.
Artemis concentrica							F.		F.	F.	F.
Tapes, n. sp. Con						413 ft.		F.			
Semele, n. sp. Con					F.						
Cardium magnum	F.								F.	F.	F.
Cardium, n. sp. Con					F.		F.				
Astarte lunulata	F.					377 ft.		F.	F.	F.	F.
Lucina costata	F.						F.		F.	F.	F.
Lucina multilineata							F.		F.	F.	F.
Arca transversa	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.	F.
Arca pexata		F.		F.			F.		F.	F.	F.
Arca ponderosa						F.	F.		F.	F.	F.
Arca americana		F.							F.	F.	F.
Pecten dislocatum				?	F.	F.	F.		F.	F.	
Pecten dentatus (?)				F.							
Anomia ephippium				F.			F.	F.	F.	F.	F.
Bullina canaliculata	F.						F.		F.		
Natica pusilla	F.						F.		F.	F.	
Natica campeachensis	F.										
Marginella limatula	F.								F.	F.	F.
Oliva literata	F.									F.	F.
Oliva mutica	F.									F.	
Pleurotoma cerinum							F.			F.	
Fasciolaria distans					F.					F.	F.
Buccinum acutum			F.		F.		F.		F.	F.	
Acus dislectum	F.				F.				F.	F.	F.
Balanus sp	F.		F.				F.				

NOTE.—The letter F denotes that the species mentioned in the first column was found at the depth indicated in the headings above.

The first point requiring discussion, in view of the facts presented in this table, is whether there is any reason to assume that the marine strata penetrated do not all represent, substantially, the same geological age.

I do not think that either the paleontological or the lithological evidence justifies any such distinction. *Pholas castata*, *Mactra lateralis*, *Tellina flexuosa*, *Arca transversa*, *A. pexata*, *Astarte lunulata*, *Buccinum acutum*, form the prominent landmarks throughout. There are three horizons especially rich in species, viz: 41,235 and 546 feet, and their neighborhoods. These are so interconnected by community of species that a real difference in their facies cannot reasonably be claimed, especially when we take into account the fact that all the shells found at the lowest levels are also found either higher up, or living in the waters of the Gulf; that, therefore, their non-occurrence in the higher strata is merely a matter of local accident, and that we might thus with propriety register all the living species found at lower levels in the columns of the higher ones. When this is done, the identity of facies becomes almost absolute, except as regards the new species.

The latter, four in number, were submitted by me to the experienced

hands of Mr. Conrad, whose description of them and remarks I hope to include in this report. He observed, in letters on the subject, that two of them especially impressed him as being of miocene type, yet that, in view of our imperfect knowledge of the Gulf fauna, it could not be positively said that these small species were not living, and had escaped observation.

It happens that one of the shells in question, *Abra, n. sp.*, occurs at 41 feet, and that quite abundantly. It then recurs at 235 feet, together with two other *n. sp.*, a *Semele* and a *Cardium*, (of the type of *C.* ,) the latter occuring also both higher up (at 56–66 feet) and lower down, (at 546 feet.) The *n. sp.* of *Tapes*, in its turn, occurs above the latter point, (at 413 feet,) as well as below, (at 570 feet.)

It would thus seem probable that whatever significance may attach to the occurrence of these new species, must apply to the formation as a whole, since they overlap both above and below.

I confess that, with all due respect for the experienced eye of my honored friend, I cannot let the consideration of the somewhat foreign type of one or two of these shells outweigh the overwhelming evidence of the general similarity of facies and preponderance of species in favor of a much more modern age than the miocene. Apart from living species, the strata in question do not contain a single shell in common with the Virginia miocene. On the other hand, most of their fauna is represented in the deposits described as pleiocene by Tuomey and Holmes, occurring on the coast of South Carolina; and, as will be seen by reference to the table, there is a still greater coincidence with those described by the same authors as "post-pleiocene." Moreover, not only the leading shells of the New Orleans strata, but the entire list, excepting the new species, might be picked up in an hour's time on the beach of any of the islands of Mississippi Sound. Other, and especially larger shells, it is true, would also be found, but it would be difficult for the auger to bring up these in a recognizable condition unless the exterior markings should be as characteristic as in the case of *Cardium magnum*, *Artemis concentrica*, *Venus cribraria*, *Pholas costata*, &c. Fragments capable of being interpreted as belonging, e. g., to the large *fusideæ*, usually washed ashore, are not wanting. Yet the probability of striking single large shells is vastly less than that of finding the smaller species, whose individuals are usually much more numerous, though when scattered on the beach they do not attract attention nearly as much as the sparse individuals of larger species.

It may be well to divest the question of the now somewhat indefinite terms which, in systematic geology, have long and usefully served in the subdivision of the later geological periods. It would puzzle most geologists at the present day to define the exact limits between the tertiary and quaternary, because in all probability no such line of division exists in nature. And when it comes to discussing whether a certain isolated formation shall be called miocene, pleiocene, or pleistocene, upon the basis of paleontological data alone, the question assumes at times somewhat of the aspect of scholastic disquisitions of the olden time. And whether we hold the Darwinian view of the origin of species, or that of Owen, or even the old one of successive independent creations, it is not at all likely that in different localities there should have been simultaneously an equal or similar accretion or extinction of species, at a time when differences of climate were already as strongly defined as now, or even more so.

If it be deemed too improbable an assumption that the four new *species might, in* view of their minuteness, have remained unobserved,

though existing in the waters of the Louisiana coast, then the formation underlying New Orleans, from the depth of 31 feet down, must be accounted of pleiocene age at least, according to the usual definition; therefore anterior in point of time to the drift.

To the assumption, however, there are almost insuperable stratigraphical objections.

The various bodies of tertiary deposits, south of the Ohio River, conform sensibly to the general outline of the Gulf of Mexico, modified by the deep embayment which, in the earliest tertiary times, reached up into Southern Illinois. Each successive accumulation rendered this embayment less profound, until at the end of the latest unquestionably tertiary epoch, (that of the "Grand Gulf" rocks, when the Mexican Gulf was merely an inland sea of brackish water,) the shore line was almost exactly parallel to the present one, if we leave out of consideration the prominence of the delta. Now the Grand Gulf rocks are everywhere found overlaid by the deposits of the southern drift or Orange sand, which in their turn are covered, either by the Loess or Bluff formation, or, nearer the coast, both of Mississippi and Western Louisiana, by a series of deposits partly marine, partly of fresh water origin, and which, from their obvious connection with the well known Port Hudson strata, I have named the "Port Hudson group." These deposits were formed, of course, previous to the existence of the Mississippi of to-day; and it would be quite incomprehensible how they could be missing in the central, and therefore presumably deepest, part of the embayment, or be there replaced by a more ancient formation.

The strata overlying the drift have been found, in Calcasieu, of no less a thickness than 354 feet. As at New Orleans, they are here found to consist of alternating strata of sand, and dark-colored clays with vegetable remains, but only in their upper portion do marine fossils occur, and, further inland, fresh-water deposits alone exist.

On the Mississippi coast, the strata have not been penetrated to a greater depth than about 50 feet; here, too, marine and fresh-water deposits are not only superimposed, but in juxtaposition. Further inland, fresh-water strata only, with underlying drift, are found; and still higher up, the drift is found underlaid by the rocks of the Grand Gulf age.

There is no reason to suppose that midway between, in the axis of the Mississippi Valley, the condition of things should be otherwise. We should, however, expect that from the presumable greater depth of water in this axis, the formation would be thicker and more prevalently marine. If in Calcasieu, at a distance from any great channel, (unless the Sabine be accounted such,) the formation is found to be 350 feet thick, it need not surprise us that it should not have been passed through at 630, in the axis of the greatest channel in the world.

Much has been said of the possible effects of the earthquakes which so frequently startle, for a moment, the inhabitants of the Mississippi Valley; and it is more than likely that the record of such events as those of New Madrid and Reelfoot Lake will be found stamped upon many a dislocated stratum hereafter. But there is yet a wide difference between such effects and the legerdemain machinery of "local upheavals," which is so readily resorted to by amateurs for the explanation of any unusual phenomenon. The geology of the northern Gulf coast has been traced with no pointed graver, but has the rough, broad dashes of a charcoal sketch; and no mere presumptions based upon partial data can be allowed to upset the general order of things. The difficulty of explaining *the presence of* a truly "pleiocne stratum at New Orleans, consist-

ently with any probable geological hypothesis, is so great that I should rather take into consideration the possibility of extinct species being found in post-pleiocene deposits, if the new shells should not turn up living in the Gulf. Sir Charles Lyell still inclines, in a measure, to the opinion that the strata penetrated in the New Orleans well may be delta deposits. This supposition, however, appears to me to be incompatible not only with what we already know of the general geology and geological history of the lower Mississippi Valley, (as shown in former papers,) but with the character of the strata themselves. They are altogether too prevalently of a marine character, so far as examined.* Nothing that could properly be supposed to be river silt occurs below 108 feet, and that resembles rather the fresh-water lagoon deposits of *Petite Anse* and *Côte Blanche* than the true river silt, formed above 31 feet. The annual, or in some seasons rather mensual floods of the river ought to cause a much more frequent alternation and change in the character of the deposits than is actually found, especially in the lower portion of the profile. A river doubtless emptied into the great estuary during the Champlain period of slow depression, but it was not *the* Mississippi river of to-day, which excavated its bed partially into these very strata, and acquired its identity during the terrace epoch of elevation.

One capital objection to the delta-deposit character of these strata, is the absence, or extreme rarity, of the true river fossil, which is rarely absent even from the marine shell beaches of the present delta, viz., the driftwood, whose macerated debris, often not exceeding a few cells loosely coherent, meet the eye in every microscopic examination of the Mississippi delta deposits. This comminution and distribution is the inevitable result of the scouring, grinding, and bruising process, which every piece of driftwood undergoes during its voyage; and while, being readily moved along, these particles are not always abundant in the river silt proper, they rarely fail to show themselves in the delta formation. There is, of course, no lack of just such fossil wood in the upper portion of the formation, near what might, for a time, have been the mouth of a river, viz., at Port Hudson, and some distance below. But that river emptied, probably, into a maze of fresh or barely brackish lagoons, interspersed with cypress swamps; and as the depression progressed, the mouth of this continental outlet, receding gradually, must have been vaguely defined as the point where the waters that deposited the bluff formation ceased to have a sensible flow.

Trusting that this report, though long delayed, may be more satisfactory to you than it could have been at an earlier period, before more extended researches had rendered an intelligent discussion practicable,

I am, very respectfully, your obedient servant,

EUG. W. HILGARD,
University of Mississippi.

Brevet Major General A. A. HUMPHREYS,
Chief of Engineers, Washington, D. C.

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* I may add, also, without attaching undue importance to the circumstance, that I found the mollusk fauna thrown ashore on the mud lumps of the delta materially different from that usually cast upon the islands of Mississippi Sound, and but slightly represented among the fossils of the New Orleans well. *Arca transversa* and *Buccinum acutum* were the only representatives of that fauna, among about twenty species collected, almost all of which were univalves.

Profile of the artesian well at New Orleans.

No.	Nature of materials, as reported by the academy committee.	Thickness.	Nature of materials, from examination of specimens.	Depth.
		Feet.		*Feet.*
1	Surface soil	2	Surface soil	2
2	Clay, blue, tenacious, uniform	15.0	Clayey silt, buff and mouse colored, with half-decayed rootlets, fibers and stems, and ferruginous spots; at bottom of stratum ferruginous concretions, sandy, concentric structure	17.0
3	Clay, coal black, containing woody matter, rootlets, &c.	3.8	Clay, dark colored, stiff, with rootlets, &c., and hard, rounded, ferruginous concretions	20.8
4	Sand and clay mixed; subtile, like annual deposits of the Mississippi River.	10.2	Silt, gray, coherent, with glistening points; under microscope pellucid quartz grains, both rounded and angular; few dark grains and mica scales	31.0
5	Clay, dark, semi-fluid, nearly destitute of grittiness.	7.0	Clay, slightly sandy, dark colored, with many iridescent surfaces, apparently casts of shells; effervescent with acids	38.0
6	Clay, same as preceding, but becoming sandier.	3.0	Clay, as above, more sandy; abundant sponge spicules; fragments of venus mercenaria	41.0
7	Sand, leaden blue, coarse; many small shells; water abundant.	0.7	Sand, coarse, rounded, with fragments of shells and cocconeis(?)	41.7
8	Shells exclusively, great variety, very compacted.	1.3	Mactra lateralis, M. sayi; arca transversa; donax variabilis; cardium magnum; tellina flexuosa, T. tenta; lucina costata; venus cribraria; astarte lunulata; abra sp. nov. Con.; pandora trilineata; oliva literata; marginella limatula; bullina canaliculata; natica pusilla; N. campeachensis; acus dislocatum; nassa acuta; coarse, rounded sand	43.0
9	Sand, like No. 7, with small shells	13.0	Quartzose sand, with little tourmaline, finer than No. 7; contains debris of small shells; arca transversa; tellina flexuosa; mactra lateralis; cardium sp. nov. Con.; balanus, echinoidea, crabs	56.0
10	Sand, clay, and shells mixed, olive colored, like mortar.	10.0	Sand, fine, bluish gray, marly, with fragments of shells and iridescent casts; mactra lateralis; tellina flexuosa; cardium magnum; natica campeachensis; naviculæ, actinoptychus, and other foraminifera; some spicules	66.0
11	Sand, coarse, dark brown; small cypress roots, pebbles. (?)	4.0	Sand, gray, coarse, coherent, sharp, with mactra lateralis, arca transversa, A. pexata, A. americana, tellina flexuosa, T. alternata, pholas costata	69.0
			Coarse white beach sand, with fragments of shells	70.0
12	Sand, coarse, light blue; no shells	5.0	No specimen	75.0
13	Sand, blue, with fragments of shells	1.0	Beach sand, with arca transversa, pexata, venus cancellata, anomia ephippium, donax variabilis, oliva mutica, buccinum acutum, balanus	76.0
14	Shells exclusively, compacted; pebbles in lowest part.	6.5		80.0
			Quartzose sand, with numerous infant shells, pholas, arca, mactra, cardium	82.5
15	Clay, olive green, tenacious	2.5	Clay, tough, greenish; little sand, fragments of shells; arca transversa, venus, balanus, foraminifera	85.0
16	Impalpable sand	3.0	Sand, like 43 to 56 feet, more greenish; fewer shell fragments	88.0
17	Clay, like No. 15	1.0	Clay, gray, sandy, with concretions of carb. lime, semi-lignitized wood. No animalculæ	89.0

Profile of the artesian well at New Orleans—Continued.

No.	Nature of materials, as reported by the academy committee.	Thickness.	Nature of materials, from examination of specimens.	Depth.
		Feet.		*Feet.*
18	Sand, gray or bluish	1.0	Sand, similar to preceding, but no shells or definite animalculæ	90.0
19	Clay, blue, with umber-colored concretions.	1.0	Silt, buff, calcareous, effervescent, coherent. No shells or animalculæ	91.0
20	Sand, blue, subtile, with some clay	4.0	Fine sand or silt, slightly effervescent and coherent; an indefinite spicule	95.0
21	Clay and sand, like No. 4	3.0	Clay, greenish and yellow, slightly effervescent. No organisms	98.0
22	Clay, like No. 19	1.0	Sand, or silt, fine greenish gray, much like that at 90 feet. No organisms	99.0
23	Sand, subtile, like German sand for fining glass.	9.0		104.0
			Fine brownish gray silt, like that at 90 feet in coherence, more clayey than preceding.	108.0
24	Clay, dark, pure, tenacious	1.0		109.0
25	Clay and sand, blue, soft; tools sink	3.0	Fine greenish drab sand, glistening with mica; small, irrecognizable fragments of shells	112.0
26	Clay, dark drab color, like tallow between teeth; effervesces with acids, leaving pores surrounded by a dark zone.	34.0	No specimen	146.0
27	Sand, clay, shells, and indurate clay	3.0	Sand, clay, and shells; arca transversa, gnathodon cuneatus, anomia ephippium, pecten, 2 sp.	149.0
28	Clay, blue, tenacious	0.2		149.2
29	Sand, &c., like No. 27	0.8		150.0
30	Clay, striated, changing into vegetable mold.	3.0		153.0
31	Cypress log, sound, with striated plates of siliceous matter.	0.5	Cypress bark	153.5
32	Vegetable mold, changing into clay, with friable shells.	1.0		154.5
33	Sand, greenish blue, with some clay	2.0		156.5
34	Clay, pure, greenish blue	9.5		166.0
35	Sand, very subtile, adhesive by little clay.	4.0		170.0
36	Clay, drab, tenacious, with lumps like chocolate.	5.0	Concretionary lumps of ferruginous micaceous sand, effervescent; no fossils	175.0
37	Clay, dark umber color, tenacious	1.0		176.0
38	Green sand, becoming clayey below	4.0		180.0
39	Green clay, somewhat sandy	2.0		182.0
40	Sand, like No. 38	1.0		183.0
41	Sand, coarse, whitish green	13.0	Fine greenish gray, clayey, micaceous sand, effervescent	196.0
42	Clay, leaden blue, not gritty; effervescent with acids.	32.5	No specimen	228.5
43	Sand, leaden blue, coarse; comminuted shells, a little clay.	21.5	Sand, like No. 28, with fragments of shells; mactra lateralis, arca transversa. No foraminifera	230.0
				235.0
			Sand, coarse, with arca transversa, mactra lateralis, tellina flexuosa, T. tenera, venus cribraria, cardium sp. nov. Con. semele, sp. nov. Con., abra sp. nov. Con., pecten dislocatum, pecten sp. 146 feet; fasciolaria distans, acus dislocatum, buccinum (nassa) acutum.	241.0

Profile of the artesian well at New Orleans—Continued.

No.	Nature of materials, as reported by the academy committee.	Thickness.	Nature of materials, from examination of specimens.	Depth.
		Feet.		*Feet.*
			Sand, coarse, effervescent, with ferruginous grains and fragments of shells and wood; arca transversa, mactra lateralis, tellina. No foraminifera	246.0
			Sand, finer than preceding, non-effervescent. No shell debris; arca ponderosa?	250.0
44	Variegated clay and vegetable mold	2.0		252.0
45	Clay, pale lead color, or dirty white, tenacious, unctuous, not gritty.	39.0	No specimen	291.0
46	Clay, sand and shells, soft mass		Fine, uniform, greenish sand, not effervescent; fragments and iridescent casts of marine shells	293.0
47	Sand, unmixed	29.0	No specimen	322.0
48	Clay, pale olive, very pure	4.0	Greenish clay, very meager	326.0
49	Sand, like No. 47	6.0		332.0
50	Clay, like No. 48	3.0		335.0
51	Sand, ash colored, coarse; artesian water.	95.0		340.0
			Mouse colored, fine, sandy material, somewhat clayey; effervescent. No definite organisms	370.0
			Sand, loose, pure, much rounded; beach sand	377.0
			Sand, as above, with shells and fragments, much worn, grains coarser; astarte lunulata, arca transversa, A. ponderosa?	402.3
			Sand, as above, but less pure, some grains cemented by iron; mactra lateralis, arca transversa, venus sp.	413.0
			Sand, as at 377 feet; tapes n. sp. Con. Mactra lateralis	420.0
			Sand, same as last; acus dislocatum	430.0
52	Sand, nearly black, subtile; a little clay; 360 gallons water per hour.	50.0	Sand, fine greenish, rounded, with conglomeratic ferruginous lumps; some linear spicules. No shells or foraminifera	440.0
			Sand, same as preceding; coarser, much rounded. No shells	450.0
			Sand, same as preceding	463.0
			Sand, same as preceding, with small bits of wood. Accidental?	476.0
			Sand, as above, with venus cancellata, mactra lateralis, tellina turbinella	
			Sand, coarse; ghathodon cuneatus, venus paphia, arca transversa, A. ponderosa, pecten dislocatum, anomia ephippium	480.0
53	Clay, blue, tenacious, firm; no water	63.5	No specimen	543.5
55	Sand, many minute shells and fragments	2.5	Dark, greenish, clayey sand; arca pexata, anomia ephippium, lucina costata, bullina canaliculata	544.0
			Coarse white beach sand; mactra lateralis, lucina costata, arca transversa, A. ponderosa, lucina multilineata, pholas costata, cardium n. sp. 235 feet; natica pusilla, nassa acuta, pleurotoma cerinum, bullina canaliculata, oliva mutica, dentalium, artemis concentrica	546.0
56	Clay, blue, firm, *tenacious*	20.0	No specimen	566.0

Profile of the artesian well at New Orleans—Continued.

No.	Nature of materials, as reported by the academy committee.	Thickness.	Nature of materials, from examination of specimens.	Depth.
		Feet.		*Feet.*
57	Sand	2.5		568.5
58	Clay, as above	16.0	Tough, brown clay, astarte lunulata, arca transversa, tapes n. sp. Con. 235 feet	570.0
			No specimen	582.0
59	Sand and little clay, of stony hardness			584.0
60	Gray clay		Gray, gritty, micaceous clay. No shells. Many foraminifera. (Pourtales)	630.0


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with regards of
Eug. W. Hil

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ON THE

GEOLOGY OF THE DELTA,

AND THE

MUDLUMPS OF THE PASSES OF THE MISSISSIPPI.

By EUG. W. HILGARD.

[Read before the American Association at its last meeting in Troy.]

[From the American Journal of Science and Arts, Vol I, 1871.]

In previous papers* read before this Association, I have communicated the results obtained during two successive geological expeditions to Louisiana, so far as the more ancient formations are concerned. It is the object of the present communication to present and discuss the phenomena of that portion of the territory explored by me, lying within what is usually considered the alluvial area, proper or Delta, of the Mississippi river. Most of these observations were made in 1867, during the first of these excursions referred to, under the auspices of the Smithsonian Institution; their publication having been delayed in consequence of want of time, on my part to carry out the large amount of chemical and microscopic work involved in the discussion, which is even yet far from being as full as would be desirable. I hope, however, to be enabled, hereafter, to continue the investigation of the subject, both in the field and in the laboratory.†

I. *The Upper Delta Plain.*

I recall to mind the fact that, as we descend the Mississippi, the older strata successively sink from view. A few miles below Vicksburg we lose sight of the older Tertiary. Thence down to the latitude of Tunica Bend, La., we find the rocks of the Grand Gulf (Tertiary) age, possessing but a very faint southward dip. Next, the oldest representative of the quaternary epoch, viz., the stratified Drift or Orange Sand, disappears beneath the water's edge near Port Hudson; while the swamp, lagoon and fluviatile beds, which have given notoriety to the latter locality, are seen above high water level not much farther south than the city of Baton Rouge.

The gradual descent and successive disappearance of these strata is not, however, altogether a phenomenon of dip, in the

* This Journal, II, vol. xlvii, Jan., 1869; Ibid, xlviii, Nov., 1869.

† For material assistance in the investigations embraced in this paper, I am especially indebted to the officers of the Delta Survey in charge of the Coast Survey schooner Varina—Messrs F. P. Webber and Henry L. Marinden, for reports of observations, and specimens furnished; to Capt. Day, in command of the same vessel, then moored at the Head of the Passes, for a boat's crew and personal assistance in the examination of the mudlumps; to Mr. Moulton, of the Cromwell line of steamers; to Captain Ed. Yorke, of the Towboat Association, and to Capt. Andrews, then of the dredgeboat at the Southwest pass, for free transportation on their respective vessels; and to Capt. Tilford and other gentlemen of the N. O. Pilot Association, for generous hospitality as well as much valuable information. For similar favors I am indebted to Dr. Copes, President of the N. O. Acad. of Sciences, as well as other members of that body. Other acknowledgments will be found in their proper place.

usual sense, but in a great measure the result of consecutive deposition; while the *surface* slope of the Port Hudson deposits is manifestly in a great degree due to denudation, and in part, no doubt, to deposition on a sloping bottom. At Port Hudson as well as elsewhere, where extensive profiles can be seen, the deposits of that era exhibit the basin shape; both on the large and, sometimes, on the small scale. In this as well as in their lithological and paleontological features, they greatly resemble deposits now forming over large areas; and where the two are in juxtaposition, it is often difficult, sometimes impossible, to draw the line between them, since qualitatively their process of formation has been manifestly the same. Both above and below Port Hudson, and down as far as Fort St. Philip, the *apparently alluvial* river banks frequently exhibit at low water edge, solid blue clays, with cypress stumps and twigs imbedded therein, scarcely distinguishable from some materials occurring at Port Hudson, Côte Blanche, and other localities *of the Port Hudson age*; and as neither can be expected to contain any but living organisms, it is, thus far, from general considerations alone, that we can hope to deduce their real age. It might seem, at first sight, that the distinction is practically of little moment; but when it is considered that the Port Hudson deposits are separated in time from those of the present era, by a large portion of the "Champlain" period of depression, *plus* the entire "Terrace" period of elevation, it becomes obvious that the distinction is one of no little theoretical, and some practical, interest. For while the Port Hudson strata yield to the augur almost invariably a considerable rise of artesian water, no such result can usually be looked for in either river or delta deposits.

I think that a retrospective view of the geological history of the lower Mississippi Valley and Gulf Coast, as developed by my observations in the States of Mississippi and Louisiana, will serve to show the probability that by far the greater portion of what now constitutes the alluvial plain of the lower Mississippi, is covered by the river deposits to a comparatively insignificant depth only; excepting where the ever shifting river channel itself has caused an unusual depth by excavation and subsequent filling up.

I have shown that toward the close of the Drift period, the place of the present Mississippi was occupied by what, but for its stupendous proportions, might be termed a torrent of fresh water, having, even as far south as the present coast line, a velocity sufficient to transport pebbles of five to six ounces weight, from localities not nearer than Tennessee and northern Arkansas; together with the smaller ones derived, doubtless,

from the same sources as the drift boulders of Missouri and Illinois.*

In the bored wells of Calcasieu, these pebbles have been found as much as 450 feet below tide level; the inevitable inference being (provided the sea level remained constant), that since the time of their transportation, the coast has suffered a depression to at least *that* extent—in matter of fact, probably, fully twice that amount.† The thickness of the drift stratum is about one hundred feet, the materials growing finer toward the top; indicating, therefore, a diminished velocity of the depositing current.

Overlying this sand and pebble drift, we find, as at Port Hudson, alternating strata of more or less lignitiferous clay and sand, 350 feet thick; a 130-foot clay bed lying on top. In its uppermost portion, this bed recalls to mind at once the variously colored clays of the Côte Blanche profile, with their calcareous concretions; but here, according to the concurrent testimony of the inhabitants and the microscope, *marine* shells take the place of the fresh-water fauna observed at the former locality. The sands which, on the whole, predominate in the lower portion, are readily distinguished under the microscope from those of the drift, by the predominant sharpness of the grains, and the occurrence of particles of lignitized wood; but I have not thus far succeeded in finding in them any other organisms. They resemble strikingly the materials obtained at corresponding depths in the bored wells in the city of New Orleans.

Few deep wells exist near the coast, in the interval between that city and the Calcasieu bores. In the only one of which I possess definite data, viz., at Salt Point on Bayou Salé, a bed of marine shells was found after passing through the first clay bed, at 60 feet.

* Miss. Rep., 1860, p. 26 and ff.; this Journal, II, May, 1866; and Nov., 1866; Ibid. Jan., 1869; Ibid, Nov., 1869.

The magnitude of this phenomenon would give it a continental significance even if it were confined to what I have termed the "Orange Sand delta," below Cairo. But as I have elsewhere stated, similar pebble streams, with slack water deposits of ferruginous sands intervening, exist in Texas; and I have the satisfaction of adding to the array of facts heretofore presented in connection with this subject, the testimony of Prof. Safford, of Tennessee; who, upon discussion, finds that the phenomena presented by the "Bluff gravel," "Ore region gravel," and "Eastern gravel" of his report are most satisfactorily accounted for, and brought under a common point of view, upon the basis set forth in my publications, above referred to.

In connection with Tuomey's and my own observations in Alabama, and farther east, those of Prof. Safford acquire additional significance, and the southern stratified drift an additional claim upon the serious attention of American geologists. Compare Prof. Newberry's interesting paper on "The Surface Geology of the basin of the Great Lakes, and the Valley of the Mississippi," where it is stated that "no deposits corresponding to the drift of the northern and western states, exist south of the Ohio river," (Ann. Lyc. Nat. Hist., N. York, ix, 213, 1869).

† This Journal, II, Nov, 1869, p. 335.

The same is true of the formation skirting the coast of Mississippi Sound. Deep wells there sometimes, though not always, strike beds of marine shells, and water possessing a considerable rise, after penetrating the uppermost clay bed; which *there* usually also contains cypress stumps, and forms the "blue clay bottom" of the Gulf coast. Sometimes, though rarely, deposits of marine shells, of living species, appear in the beds of streams. But so far as I know, their occurrence is limited to within a moderate distance from the general coast line; so that the great body of the formation underlying the upland parishes of East Louisiana, the Attákapas and Calcasieu prairies, as well as the coast-belt of prairies in Texas, consists of marsh, lagoon, and fluviatile deposits, with, probably, many an inlet or estuary of a more or less brackish or marine character.

Obvious as is the conformation of this littoral belt to the outline of the Gulf coast, the Mississippi valley influences it only in so far, as that its strata have here, probably, their highest absolute elevation,* and farthest extension northward. The latter circumstance is the natural consequence of the existence of the depression which, at least since the opening of the Cretaceous period, has determined the outline of the formations southward of Cairo—an embayment which, with every succeeding period of deposition, became less concave, until at the close of the Grand Gulf epoch, the concavity had all but disappeared. During the period of slow depression which characterized the Port Hudson era, the present general coast line must have been established; and when upon the reversal of the movement of subsidence, the waters of the continent began to be discharged through what is now the lower Mississippi valley, the erosion seems to have been checked everywhere, save perhaps in the main channel, by the tough cypress swamp clay which now forms the immediate substratum of the lower littoral belt, and extends far into the waters of the Gulf.

It is incredible that the deposition which occurred along the whole Gulf coast from Indianola to Mobile, should not have taken place also in the main axis of the depression which, as the trend of the formations shows, had in a great measure been filled up. Yet, inasmuch as this was the deepest portion of the area, it is to be expected that here, if anywhere, marine deposits should extend far inland. We shall not therefore be surprised to find that, as Pourtalés has proven from the soundings made under the direction of Gen. Humphreys, the Mississippi river flows on marine beds, at New Orleans and Bonnet Carré. It would rather be remarkable if such beds should *not* appear even much higher up the river, since even in the comparatively

* As regards the main body. At Weeks' Island and Petite Anse, and probably at Côte Blanche and Orange Island, their elevation exceeds that at Port Hudson bluff.

insignificant valley of Pearl river, they have been met with in the latitude of Baton Rouge,* about 30 miles from the coast.

It is, doubtless, owing to the formation of these swamp deposits, and their subsequent resistance to denudation during and since the Terrace epoch of elevation, that the main body of the truly alluvial delta is thrown so far beyond the general coast line,† out into the Gulf. It is the shallow "blue clay bottom," so well known to navigators on the Gulf coast, which forces the great river to advance its mouths so rapidly toward deep water, by the accumulation of its own deposits; and the borings made at New Orleans have shown how slight is the thickness, even at such an advanced point, of the river deposits proper, overlying the older formation.

I owe to the active interest taken in this subject by Gen. A. A. Humphreys, U. S. A., an opportunity of examining, not only the specimens collected during the boring of the artesian well at New Orleans by a committee of the New Orleans Academy of Sciences (so far as they were preserved from destruction during the war); but also those obtained in the soundings made by the delta survey under his charge, upon which a very able and minute report of a microscopic examination had previously been made by Mr. L. F. Pourtalés. Upon the strength of the data furnished by the latter, as well as by the profile constructed by the committee of the Academy (reproduced in the "Report on the Physics and Hydraulics of the Mississippi river"), Gen. Humphreys concluded that at Bonnet Carré and New Orleans, the river flows on an ancient sea bottom, which he conjectured to be of Tertiary age. Sir Charles Lyell having questioned the correctness of this view, Gen. Humphreys obtained from the N. O. Academy as complete a suite of specimens of the borings as could be collected, and referred them to me for examination. The first results of this investigation are given, in substance, in the first volume of Lyell's Principles of Geology, 10th edition, p. 459; they were based substantially upon the determination of the visible shells (mollusks) contained in several of the specimens, embracing, fortunately, most of the important horizons mentioned in the profile. I have since gone over the whole ground, in the microscopic examination of all the available specimens, with a view to determining their (marine or fresh water) character, and the admissibility of the supposition that they might belong to the delta formation proper.

My detailed report of this examination will, I presume, be published before long.‡ Unfortunately, most of the specimens

* Miss. Rep., 1860, p. 156.

† Drawn, say from the mouth of Pearl river to Belle Isle, the most advanced outpost of the Port Hudson deposits on the Louisiana coast; which line will pass near the city of New Orleans.

‡ In Rep. of the U. S. Engineer Dept., for 1870.

representing the important clay strata (of 34, 32½, 39, and 63½, feet respectively), were missing; but as regards the rest, 51 in number, I found almost all derived from a lower level than 31 *feet*, either characterized by marine organisms (shells, corals or foraminifera), or of such a character as, by their obvious connection with the others, to put them in the same category, although devoid of fossils. I cannot omit to mention in this connection, the extraordinary scarcity of marine organisms in some of the specimens brought up in sounding *off*, *on* and *inside* the bars of the Mississippi Passes; the most patient search, even after concentration by washing, having failed to bring to light anything but minute fragments of wood, root and other vegetable fibers, and remnants of Naviculæ. These specimens had, it is true, been obtained during a period of high water; and others, collected at corresponding points but at a different season, showed abundance of foraminifera and even some visible shells. But in view of these facts, it is quite intelligible how in an estuarian formation, forming at the outlet of the continental waters, many portions may have remained destitute of any vestige of marine life, though perhaps deposited in strongly brackish water; while any slackening in the rate of depression would promptly cause a predominance of the fresh over the salt water, a stagnation, and consequent deposition of clays; which would be nearly or quite free from vestiges of marine life. Such is the case in *some* of the few clay specimens from this bore, which I have had the opportunity of examining; but others I have found to contain not only foraminifera, but abundance of shells. In the clay occurring at the greatest depth reached—630 feet—Mr. Pourtalés reports an abundance of foraminifera.

The specimens from the several beds contained altogether about 50 species of mollusks, of which 40 were in such a condition as to be determinable with certainty. Of these, 36 were species now living in the Gulf, and 4 were new.

The latter (belonging to the genera *Cardium*, *Abra*, *Semele* and *Tapes*) I submitted to Mr. Conrad for determination and description. He remarks that while they (one of them especially) seem to be rather of miocene type, and not known to be now living in the Gulf of Mexico: yet our knowledge of the fauna of the latter is so imperfect thus far, that it cannot be asserted that the species are not now inhabitants of the Gulf waters.

As regards the distribution of the species, there is no material difference from the highest to the lowest level, the leading and predominant species being everywhere about the same, and coinciding in a marked manner with the fauna collected by myself on the beach of Ship Island in the Mississippi Sound;

though quite different in the prevalence of species, from that now cast ashore on the islands of the delta. One of the new species, moreover, occurs abundantly in one of the very first shell-beds; and three of them at the depth of 235 feet, as well as, in part, still lower down.

In view of all the facts bearing on the case, the most probable conclusion is that the marine formation penetrated in the New Orleans well is altogether independent of the present delta formation; that, on the contrary, it is the equivalent in time of the Port Hudson deposits, which everywhere near the coast assume a marine facies; and would necessarily possess that character in an increased degree, where the deepest depression existed.

The thickness of the alluvium proper in the alluvial plain will, of course, vary in accordance with the degree of denudation that the older formation may have experienced during the era of upheaval; and it is futile to attempt an estimate of the amount of alluvium deposited by the great river since the beginning of the modern era, until numerous observations shall have placed us in possession of data allowing us to form an approximate estimate of its depth in the several portions of the alluvial plain. While there exist in it, doubtless, a number of ancient river channels, we already have proof also of the existence of ridges of more solid and ancient ground, far out in the delta plain, which seem to have caused the eastward deflection (parallel to the Tèche and the main Mississippi), of Bayou Lafourche as well as of the minor channels. I have heretofore* alluded to the apparent *general* cause of this deflection, viz., the barrier of drift materials accumulated, perhaps, upon a Cretaceous nucleus, which is presented by the chain of Five Islands—Belle Isle, Côte Blanche, Weeks' Island, Petite Anse and Orange Island—extending from Atchafalaya to Vermilion Bay.

The very variable depth of the alluvium is well exemplified by the borings made for water and gas, in the city of New Orleans, by Mr. J. B. Knight, of that city. Its lower limit seems to be almost everywhere marked by a stratum of liquid mud, beneath which appears the first shell bed. It is from this mud stratum, which is struck at depths varying from 31 (in the well of 1856) to 56 feet, that combustible gas is frequently found to issue in considerable abundance, and with a pressure (as reported by Mr. Knight) of from 1½ to 3 pounds per square inch. The discovery (which was made by Mr. Knight in boring an experimental well for water, on his premises) at first created considerable excitement, as it was thought the natural gas might successfully compete with that of the gas company,

* This Journal, II, Jan., 1869, p. 88; ibid, Nov., 1869, p. 343.

which it was said to equal in quality. That this was but an indifferent compliment to the company's product, may be judged from the composition of the natural gas, which was analyzed by Prof. J. W. Mallet, then of the University of Louisiana, with the following result:

Gas from "Knights' well," 170 Gravier street, New Orleans.

Marsh gas,	91·81
Carbonic acid,	2·97
Nitrogen,	5·32
Hydrocarbons condensible by bromine,	trace
	100·00

The gas issued at the rate of one and a half cubic feet per hour, with a pressure of 1·6 inches of mercury. It was reached at a depth of 40 feet, and was accompanied by a considerable flow of faintly saline water.*

Mr. Knight sunk numerous wells in different portions of the city, and states that gas was struck nearly everywhere at depths varying from 37 to 56 feet; its amount, in one and the same region, being sensibly proportional to the diameter of the bore. In a few cases, an extraordinary amount of gas, under strong pressure, was struck. In an article published in the New Orleans Times, of March 19, 1870, it is stated that "at the old Washington Artillery building on Girod street, a pipe was driven for water, and the gas flowed through in such a volume, that when ignited it fed a flame 15 feet in height, which was with difficulty extinguished; and when it was at length choked out, it carried up several cart loads of sand in a single night. Yesterday a similar phenomenon presented itself on the edge of the sidewalk in Camp street, opposite Lafayette square. A pipe about an inch and a half in diameter had been driven into the ground for water, when at the depth of 60 feet, a rush of gas, accompanied by water and sand, was forced through to a distance (height) of twelve or fifteen feet above the top of the pipe. This continued for two hours, in spite of all efforts to suppress it; and the result was a deposit of sand mixed with fine shells and pebbles, amounting to at least three cart loads. Finally the workmen succeeded in closing the pipe, and forcing it through the gas-bearing stratum."

The supply of gas was in the end, however, thought inadequate for practical purposes; while the original object of obtaining drinkable water was attained to a limited extent only. Mr. Knight says in a letter on the subject, that he has "found great irregularity in the thickness and character of the strata,

* See analysis beyond.

and it is impossible to tell the character of the water or the depth at which it will be found, before trying. At two places distant about 1,500 feet, I obtained, in one, at the depth of 48 feet, a free supply of clear water strongly impregnated with iron; in the other, no such water could be found at the depth of 78 feet."

Attention having been called to the subject, a "find" of gas was next reported from the parish of Lafourche, said to rise with a pressure of 10 pounds to the inch. I have been unable to learn whether or not this occurrence of gas is identical with that described to me by Col. Thibodeaux, of Thibodeauxville, as keeping up a continual agitation of the waters of the "Bayou bouillant," on the lower Lafourche. So far, no practical application of this source of gas has come to my knowledge.

As regards, then, the upper delta plain, there can be little doubt that, like the Calcasieu and Attákapas prairies, it is underlaid by the detrital deposits of the stratified Drift, at a depth which may fairly, *à priori*, be supposed commensurate, in a measure, with the importance of the neighboring channels; viz., the Sabine on one hand, and the Mississippi on the other. About midway between, the Cretaceous ridge marked by the line of outliers from Lake Bisteneau to Chicotville or Petite Anse, has caused these same deposits to appear at the surface.* The overlying swamp, lagoon and estuarian deposits of the Port Hudson age, will vary both in thickness and in the (marine or fresh-water) character of their materials, in accordance with the conformation (relative to the ocean) of the surface upon which they were deposited. And the alluvial deposits proper will, in like manner, vary in thickness in accordance with the degree of denudation previously experienced by that older formation, but appear to be little greater on the alluvial plain near New Orleans, than it is sometimes found to be in the Yazoo and Tensas bottoms.†

It is important to note that, under this point of view, the ultimate success of an artesian bore at New Orleans becomes a matter of certainty—a question of depth alone. All water obtained in the Port Hudson strata possesses considerable rise, but is usually too strongly mineral to be desirable for every-day use. The waters obtained in the Orange Sand, on the contrary, are always remarkably pure, and when struck *beneath* the Port Hudson deposits cannot fail to possess a proportionate rise, as in Dr. Kirkiman's bore, on the West Fork of Calcasieu. The waters of the Port Hudson strata would, of course, require to be tubed out.

[To be continued.]

* This Journal, II, Nov., 1869, pp. 332, 342 and ff.

† Humphrey's and Abbot's report, pp. 98–100, et al.

II. *The Lower Delta and the Mudlumps.*

A glance at the map shows that in descending the Mississippi from New Orleans, we find a narrow strip of land only ¼ to 3 miles wide, dividing the river from the waters of the Gulf; from the head of Oyster Bay opposite Pointe à la Hache (about half way between the city and the head of the Passes), down to the mouths. Such, at least, is the case on the left bank; on the right, the "neck" begins a few miles below Fort Jackson. Down to the forts, the aspect of the "Coast" is generally pretty much the same, where its original character has not been lost by cultivation or encroachment of the river. Nearest the river, and highest above water level, are the sandy "willow battures," where the willow, mingled with and occasionally replaced by the cottonwood, forms the predominant growth. Beyond lies a belt of woodland, timbered chiefly with live-oak, magnolia, and cottonwood, often deeply veiled with long-moss; this belt embraces the richest and most durable soils of the "Lower Coast," and is mostly occupied by magnificent plantations of sugar cane and orange orchards. Beyond these, loom in the distance the sombre-hued, moss-curtained denizens of the cypress swamp, their tops forming a level platform sharply defined against the horizon. Between the swamp and the water's edge, seaward, there usually intervenes a zone of reeds, with here and there a stunted cypress, bay, or candleberry bush, where the salt water has but slight access.

While such is the general order of succession of these belts of vegetation where they coëxist, either or both of the two middle ones may locally be absent. Such is always the case where the "neck" is very narrow, as happens below the forts. Thence to the mouths of the passes, the willow batture and the reed marsh alone, with few exceptions, form the barrier between the river and the sea; it is traversed by numerous small bayous, some of which are in great part the work of the duck-hunters that supply the New Orleans market, and whose pursuit leads them to penetrate the marsh for the purpose of reaching the favorite resorts of their game. These bayous increase in frequency as we descend, and in approaching the mouths of the passes, the intervals between them become smaller, until they gradually become sheets of water dividing islands; and finally, just inside the bar, we have the latter resolved into numerous individual "mudlumps," dotting the surface of the sea, on both sides of the main channel.

Sir Charles Lyell remarks (Principles of Geology, 10th ed., p. 448), that the phenomenon of the mudlumps is without parallel, so far as known, in the delta of any other river. The same remark might, I think, appply to two other peculiarities, viz: the protrusion of the long neck of land into the Gulf; and the fact that, after failing to send out any branch of importance for a hundred miles the great river suddenly divides at one point into three widely divergent branches, the middle one of which (the South Pass), forming the direct continuation of the channel, is the smallest, and has long ceased to be navigable. Evidently, a strong extraneous obstacle alone could turn aside the powerful current, and permanently resist its erosive and undermining action. And now, the channel which carries the main current (the Southwest Pass), faithful to the old tradition, is rapidly pushing out into the Gulf its narrow bands of reedy marsh, without a branch of any consequence in ten miles from the head of the Passes to the light-house.

A glance at the coast lines, as well as at the intricate ramifications characterizing the deltas of the Rhine, the Po, the Danube, the Ganges, or the Hoang-Ho; or the broad inlets forming the mouths of the rivers of South America, will show the uniqueness of the Mississippi mouths; the Nile and the Lena alone exhibiting a general form at all analogous, yet very distinct in detail. For the islands off the Lena mouths are not "mudlumps;" and the tongue of land separating Lake Menzaleh from the Damietta branch of the Nile, is a mere sand-bar, exhibiting no analogy save that of form, with the remarkable "necks" of the Mississippi Passes.

It would be fair to infer, à priori, that some connection exists between the exceptional phenomenon of the mudlumps, and the exceptional form of the delta; and that such is really the case, can hardly be doubted upon a candid investigation of the facts. So far from being an unusual phenomenon, *the mudlump-formation appears to constitute the normal mode of progression of the Mississippi mouths;* not only at the present time, but for many ages past; perhaps ever since the broad flood of the Terrace epoch subsided into the present Mississippi.

The characteristic features of the mudlumps have successively been described and discussed by Sidell,* Forshey,† Chase, Beauregard and Latimer,‡ Thomassy§ and Lyell.‖ Yet as the phenomena are nowhere described in their entirety, I will here, as briefly as possible, recapitulate the important points.

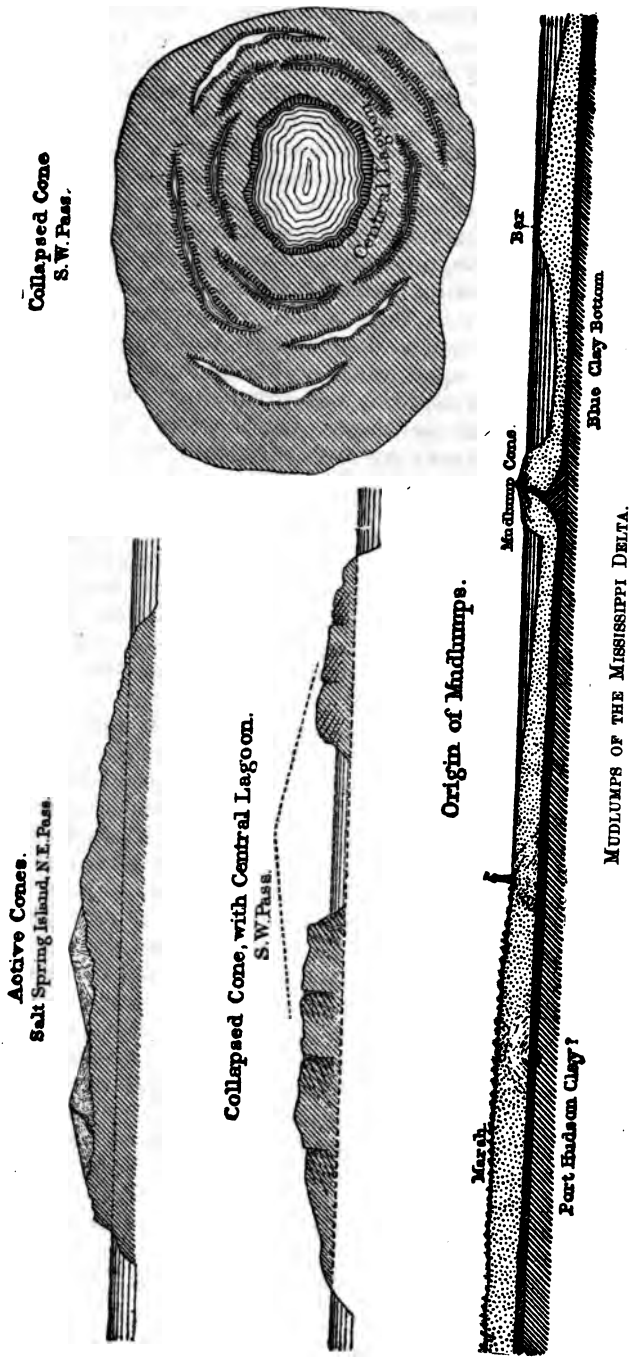
* Report to Capt. Talcott, 1839, in Humphreys and Abbott's Report, App. A.

† MS. Report, 1850.

‡ Report of the Board of Engineers for the Examination of the Mississippi; Congress. Doc. 1852–53.

§ Geologie Pratique de la Louisiane, 1860, Chap. VI.

‖ Principles of Geology, 10th edition, 1868; vol. 1, p. 449.


Collapsed Cone
S.W. Pass.
Active Cones.
Salt Spring Island, N.E. Pass.
Collapsed Cone, with Central Lagoon.
S.W. Pass.
Origin of Mudlumps.
Bar
Mudlump Cone
Blue Clay Bottom
Marsh
Port Hudson Clay?
Mudlumps of the Mississippi Delta.

The mudlumps originate in upheavals of the bottom, in the region lying between the extreme point of the mainland and the crest of the bar, at the main outlets of the passes. They all lie within a distance of from one to three miles from the axis of the main current, and nowhere extend into the bays intervening between the several active mouths. The pilots are under the impression that they form more frequently in the main channel than elsewhere; but allowance must be made for the natural infrequency of their observations outside of the latter; so that only the more obvious and remarkable changes of the bottom, when occurring outside of their regular range, would be likely to come under their notice. *A priori*, it would seem probable that inasmuch as the resistance to the upheaving force, other things being equal, must be less in deep than in shallow water, the lumps would rise more frequently and more rapidly in the channel than elsewhere. On the other hand, the denuding force of the river current must greatly diminish the chances of any such upheaved mass appearing above the surface, or even becoming manifest by a diminution of depth, when progressing slowly. Weighing these considerations against each other, I think a balance remains in favor of the pilot's opinion: the more as concurrent testimony goes to show that whenever the channel is changed, either by the accumulation of deposit or the interference of a mudlump upheaval, the old channel is promptly occupied by mudlumps *throughout* the abandoned portion.

As regards the rapidity of the upheaval, it appears to vary from an almost secular rate, to that of several feet in 24 hours. It has been rumored that lumps had been seen to rise visibly, and burst open like a bubble, but I have been unable to trace the statement to any reliable source, and it is discredited by the pilots. The most rapid rise of which I have obtained reliable information was witnessed by Capt. Andrews, of New Orleans. He states that a steamer having run aground about nightfall inside the bar, her bow being on a mudlump in about 2½ feet of water, he towed her off during the night, and in the morning found the imprint of her bow 18 to 24 inches above water, in the soft mud. Allowing for the possible maximum influence of tides in favor of the difference observed, the minimum rate of upheaval, according to these data, still amounts to one inch per hour. Nor is this the only case in which a rapid shallowing of the water has been observed as a consequence of the grounding of large vessels. This has usually been ascribed to the accumulation of deposit in the slack water so formed, and in many instances this may have been the true cause. But this explanation can hardly apply to the case detailed above, and it is reasonable to suppose that the shock of a grounding vessel may

in many cases prove "the hair that breaks the camel's back," when acting upon a portion of bottom just about to yield to the upheaving force, and therefore in a state of unstable equilibrium. Future observations, however, will readily settle the question.

Of authentic observations illustrating ordinary rates of rising, I quote the following remarks of Mr. H. L. Marindin, U. S. Coast Survey, who in 1867, while engaged in the survey of the mouths, at my request paid considerable attention to the phenomena of the mudlumps, and made an interesting report to me on the subject, dated June 20th, and accompanied by specimens.

"Since the first examination of the mudlumps on Southwest Pass Bar, there have appeared numerous lumps in the vicinity of the main channel, whose appearance cannot be attributed to other causes than the upheaval of the bottom by some unknown agency; since tidal observations made during the month of April, May and part of June, show no material decrease in the height of water in the river, other than the daily ebb of the tide. In one instance, also, on this bar, it has been ascertained from surveys made at different times, that where in the month of April a channel with fifteen feet of water existed, there is now a lump, doubtless still forming, with only six feet of water on it at the highest stage."

Making allowance for a possible accumulation of deposit, the rate of rise cannot, in this instance, be estimated at less than two feet per month; which, so long as the lump remains under water, seems to be no unusual amount. When, however, the surface of the water is once reached, the rising becomes slower or ceases altogether, owing probably to the greater weight acquired by the material upon its emergence. At least, I have failed to find much above tide level, any material which did not bear distinct evidence of its having been formed, not by river alluvion, but by the action of the regular mudsprings; which, if not now active upon all the lumps, have demonstrably been instrumental in forming the great majority of the masses now above water level.

I do not know that any one has ever witnessed the first outburst of a mudspring on a newly risen lump; but we find them in all stages of progress, from the islet bearing its first tuft of rushes, to the active cones glistening in the sunshine, and from time to time, when an unusually large gas bubble rises, spattering the liquid mud (which usually flows in a quiet stream) all over the slopes; then the half-extinct cone, in whose crater a little pool of salt water is at long intervals agitated by a gas bubble; then the extinct and collapsed cone, surrounded by a circular moat and Somma-like ring-wall; next, the old lump of

jagged outlines, whose disintegrated materials are rapidly yielding to the combined attack of rain, sunshine and waves, till something looking like a large stump of a tree is all that remains of an island of several acres; and finally the shoal, marked by dangerous rollers, whose surface, on a calm day, still exhibits the concentric markings corresponding to the several cones which originally built up the island.

I regret being unable at the present time, to present accurate sketches of these several stages of "the mudlumps' progress." I hope to do so hereafter, but for the present must confine myself to the approximate outline representations given in the plate, and a brief description of the several stages as observed by myself in 1857.

Nascent Lumps.—As regards the first, it is probable that a good many lumps never pass beyond that stage of development, for the reason that, so soon as the resistance is materially increased by the emergence of a portion above the surface of the water, the upheaving force seeks a vent elsewhere.

Either the mud or gas-spring breaks out beneath the water, and becomes perceptible only by the more or less regular and localized evolution of bubbles on the outskirts of the lumps; a very common phenomenon in the neighborhood, not only of new and active lumps, but also about extinct ones, which are in course of demolition by the waves. On the extensive sandy shoal off Stake Island, on the Southwest Pass, such subaqueous gas-springs may be observed in great numbers.—Or it may happen, that another portion of the bottom, now offering less resistance than the mudlump, will, in its turn, give way before the upheaving force, till the same degree of emersion is obtained, or a vent is opened.

I have been unable to ascertain how high any mudlumps can rise bodily above the water without the appearance of a vent. As much as three feet has been observed with certainty; but unless the fact that it is a new upheaval be historically known, it must be extremely difficult to ascertain it, unless, by actual access to the interior, it can be shown that its surface strata are old river deposits, which can readily be distinguished from those formed by mudlump vents. Yet these might, during the elevation of the lump, have been removed by the current. At all events, I have failed to find on the surface of any lump much above tide-water, anything like true river alluvium; the visible material being either such as is now formed by active vents, or, (as on the lower slopes), that which obviously results from the disintegration of the former, being altogether devoid of structure.

It is said that lumps sometimes sink from view again after bare emergence. I know of no authentic example, but it

seems likely enough that upon the formation of a large vent elsewhere, such a thing might happen; especially if, as I think probable, mudsprings and mud-cones form *beneath*, as well as above the water.

Active Cones.—In the second stage, that characterized by the formation of the active eruptive cones, mudlumps offer an aspect so strikingly like that of the mud volcanoes of Tuscany, as to stagger the observer's geographical consciousness. The most striking example of the kind existed, at the time of my visit, off Pass à l'Outre, on the south (right) side of the channel. The island* is about an acre in extent, and besides the active vents (of which there are seven), we perceive on the southern portion the remnants of long extinct craters, in various degrees of advancement toward old age and degradation, and partially covered with vegetation.

The cones on the north or channel side, at a distance, present a glistening surface, and those possessing a central vent only are very regularly and smoothly conical. Of these there are four, the diameters of the bases ranging from eighteen to fifty feet, and their elevation from one to two and a half feet above the general level of the island; making the angle of the slope from 5° to 8° only, instead of 25° to 35°, as given in the published sketches. I have seen no undisturbed cone whose slope exceeded about 12°. The slope is, of course, essentially a function of the thickness and character of the mud; which in the present instance flows from the circular basin at the summit, 4 to 8 ins. in diameter, in a regular, creamy stream, interrupted occasionally only by a gas bubble; which, if the mud be thick, spatters it about to some extent. The mud-stream varies from 3 to 4 gallons per minute in the largest (eastern) cone, to a pint or two in the less active ones; sometimes, in running down the sides, it spreads over as much as $\frac{1}{3}$ of the circumference, but usually forms a stream 4 to 8 inches wide, serpenting down the slope between banks formed by its own solidification, as does a lava stream. As these banks grow in height by drying, on the edge of the crater, they gradually compel the mud to rise higher before it can flow off; whereupon, after a while the column overflows at another point of the circumference, where the same play is then repeated. In the meantime, the previous mudstream has an opportunity of consolidating, drying more or less, and undergoing a variety of chemical changes dependent upon the character of the water and the duration of the exposure to the air, which manifest themselves in changes of color and consistency; by these the individual streams are distinctly defined from one another. Each one forms, of course,

* It was named Marindin's Lump by the crew of the U. S. Coast Survey Schr. Varina, and I shall allude to it under that designation.

a more or less irregular portion of a conic surface, the cross section being more or less lenticular.

There results, as may be supposed, a very peculiar structure or stratification, unlike anything usually seen outside of volcanic districts, unless, perhaps in the somewhat analogous case of the lee side of dunes. It may roughly be compared to the upper half of an onion. It is needless to say that, once seen, it cannot readily be mistaken for anything else; and its absence must be held as proof conclusive of an absence of genetic analogy.* The thickness of the layers rarely exceeds 1½ inches; their colors vary from dark mouse-color and bluish gray, through dun and buff, to rust-color and red; the materials, from hard, plastic clay, always containing a great deal of fine silex and more or less coarse sand, to sandy clay and, rarely, clayey sand; the selvedges are frequently marked by iron rust and mica scales. Where, as is frequently the case, neighboring cones are confluent at their bases, the structure is of course complicated in a manner readily imagined.

As regards the gas evolved (which is in all cases inflammable), the small proportion its bulk bears to that of the mud simultaneously ejected (about $\frac{1}{25}$ to $\frac{1}{30}$ at Marindin's Lump), at once does away with the impression mostly entertained, that the gas bubbles bring up the mud with them. The latter comes up with a steady flow, evidently the result of static pressure, and is only from time to time agitated by a gas bubble, larger or smaller according as the mud is more or less consistent. We sometimes find, about extinct cones especially, lively gas springs in which the proportion of gas is considerably greater, than happens in any active cone that has come under my observation; but in that case, it is almost always accompanied only by *water*, as though its source were above the stratum which furnishes the mud. For, a glance at the river deposits forming around the lumps, at once shows that they are totally different from the fine, clayey material of which the cones are formed; nor is it credible that the mere passage of a current of water and gas through such deposits, or in fact, *any consolidated materials*, should produce such a perfect, creamy mixture as that ejected from these craters.

Extinct Cones.—Good examples of cones whose activity has nearly or quite ceased, may be seen off the Northeast Pass. Here the material is somewhat sandier and firmer than the mud ejected at Passe à l'Outre. While at the latter place it was difficult to reach the craters without being hopelessly

* Vide Thomassy's remarks on the Five Islands, etc., Géol. prat. de la Louisiane, chap. viii. With even less show of reason a similar origin has repeatedly been claimed for the low circular mounds which dot a large part of western Louisiana. They consist exclusively of unstratified sandy materials, and are doubtless the result of animal activity—probably of the large ant.

bogged, they can readily be reached almost dry shod at the Northeast Pass. Here, also, the top layers were peeling off in large concave "flakes," from the effect of sun-cracks and drying; such a surface again overflowed by mud would add another singular feature to the structure of the cones, which may also be noticed in many sections of ancient ones.

The vent of a large cone in this region (see Plate) formed a basin about 8 inches diameter, containing a puddle of salt water covered with an iridescent ferruginous pellicle, disturbed at long intervals by small gas bubbles. Evidently, the resistance in the large cone, elevated about 10 feet above the water level, had become too great for the ejection of mud; in consequence whereof, a lively little cone was glistening and bubbling at a level several feet lower, near the foot of the old cone. *But the testimony of the pilots goes distinctly to show, that the active cones become more lively, and dormant cones resume their activity, at high stages of water in the river.* At the time of my visit, the water was at an unusually low stage.

Collapsed Cones.—The cones, especially the larger ones, appear to be unable to survive for any great length of time the cessation of activity. The change that occurs seems to be, in all cases, a sinking of the central portion, often to such an extent that its place becomes occupied by a pool or lagoon, surrounded by a circular rim whose strata incline *away* from the center at angles invariably much steeper than is found in any recent cones, from 20° to as much as 45°. Outside of this first rim there mostly appears a series of concentric crevasses, sometimes several feet in width and in depth; and the annular segments thus brought to a level by a subsidence, also exhibit the singular feature of a *steeper* inclination of the lines of deposition, than is found in any cones now forming. The seeming anomaly of this fact caused me to observe the phenomena closely; but I have been unable to find an exception to the rule; and I have been led to doubt whether in some cases, instead of true eruption cones, these collapsed areas and their surroundings may not be the remnants of the original upheaved "bubble." The objection to this interpretation is the character of the material, which, excepting in a few cases on the Southwest Pass, is altogether unlike the present river deposits, both in structure and composition.

A most perfect exemplification of a large central lagoon (100 feet by 75) surrounded by an elevated rim and several successive, concentric "moats," also in part filled with water, occurs on one of the numerous mudlumps S.W. of Stake Island, on the Southwest Pass (see Plate). The central portion does not always, however, sink out of sight; sometimes a conical mound is still observable, as the center of the more or less circular,

concentric crevasses, which a close inspection shows to exist on almost all lumps not too far advanced towards decrepitude. Many islands exhibit several such centers and systems of crevasses, indicating, probably, the previous existence of cones, sometimes several hundred feet in diameter, greatly exceeding the largest now in a state of activity, both in diameter and original height.

Degradation and Disappearance of Lumps.—The direct action of the waves, unassisted by atmospheric agencies, produces but little effect upon the yielding, but tough and coherent material of the cones. The heaviest breakers and rollers spend their force in vain against the clay shoals which render most of the lumps so difficult of access. The unwary will often be tempted by the deceptive, rock-like aspect of this material, to jump into the shallow water and wade ashore; but a plunge knee-deep into the apparent solid will frequently reward his temerity. Yet so long as this mass, which shows plainly the peculiar, concentrically banded mudlump structure, remains constantly covered with water, the waves rolling over it produce but little impression.

Not so with the portion that projects above water, which is alternately exposed to rain, sunshine, and the wash of waves. Especially where the material is clayey, these agencies combined soon produce a change in which the structural as well as the paleontological characters of the original material are totally obliterated. A rain falling upon a fresh surface of the latter, causes it to swell; then, upon exposure to sunshine, it will contract into prismatic cleavage-forms. A slight rain, or the spray itself, will then cause the extreme surface to crumble into, and partially fill up, the cracks; when the swelling consequent upon a thorough wetting, by either rain or waves, will force them to open still more, while streamlets of fluid mud follow each retiring wave; which, perhaps, has thrown up, and left high and dry in the cracks, a dozen species of shells, entirely foreign to the mudlump mud itself. It is thus that the structureless, tough soil of the general surface, and of the beach of the mudlumps, is formed; and to it alone apply the descriptions given of the mass of the mudlumps, by Sidell, Thomassy and Lyell, as a "homogeneous, tenacious mud."

A frequent repetition of this process involves, of course, not only a rapid direct degradation of the lump, but it causes it to be cleft into fragments by rents gradually progressing from above downward, which rapidly increase the surface exposed to attack; and eventually, some large wave, in retiring, carries down with it a huge prismatic slice, leaving behind an almost vertical cliff. This is carried away in its turn, and thus, attacked from all sides, an island of considerable size, after

passing through a variety of middle stages in which it strikingly resembles masses of trap or basalt, magnified into distant mountains by the peculiar optical delusion prevailing in the region,* is finally reduced to what, at a distance, appears to be the stump of a tree. At last, some storm sweeps away this last monument of the disappearing lump, and white-capped rollers alone mark, thereafter, the higher points of the mud-shoal.

I have best observed these phenomena of disintegration in every stage of progress, among the mudlumps off the Northeast Pass, where the fanciful, cliff-like forms, figured by Thomassy, Sidell, and Lyell, may be seen to perfection.

It is said that there are no mudlumps off South Pass or Grand Bayou; a statement which may require to be taken with a grain of allowance, but agrees with the general impression that the mouths discharging the largest amount of water, also exhibit mudlump activity on the most extensive scale.

The Southwest Pass is the main outlet at the present time; the area inside the bar is thickly studded with mudlumps, chiefly west of the channel; and as before stated, lumps have risen there repeatedly under the eyes of the pilots and survey parties. Yet there is not there, at the present time, a single *active* cone, so far as I am aware; although salt water and gas springs are of frequent occurrence, both on and around the islands. There is a marked difference between the river deposits as well as the mudlump materials of Passe à l'Outre and Southwest Pass, the latter being decidedly more sandy, and sand bars taking the place of the mud flats off the former. Whether this circumstance (the natural result of the greater swiftness of the current in Southwest Pass), is connected with the absence of active cones, it may be too early to discuss. Some very lively springs on a large mudlump off Stake Island on that Pass, in which the gas emitted is about equal in bulk to the water, rise in small basins excavated at the foot of a large cone which must have been 15 to 18 ft. high; but the material they bring up is so very sandy that the water runs off perfectly clear.†

Mudlumps in the Marshes.—I have before remarked, that at the present time, the upheaval of mudlumps on the passes, and subsequent silting up of the shallows between them (by river deposit, as well as by the degradation of the lumps themselves,) seems to be the normal mode of progression of the delta. The more advanced portions of the narrow bands of shore now

* Caused probably by a faint bluish haze, through which an island a quarter of a mile distant and 15 feet high, appears to be a wooded mountain with rocky escarpments, and at its foot a wide spreading city—which suddenly resolves itself into a row of grave white pelicans perched on the beach and taking wing at the approach of a boat.

† See analysis of the water of these springs, below; marked "S. W. Pass, I."

forming along each one of the passes, are historically known to consist of mudlump-chains; and in the absence of any plausible presumption to the contrary, as well as of any parallel example in other rivers, it is reasonable to surmise, that not only the shores of the present passes, but also the neck, *at least* from Pointe à la Hache down, owes it formation and peculiar features to the same agencies.

We have seen how rapidly and completely the joint action of the waves and atmospheric agencies accomplish the degradation of elevated lumps to the common level of the tide; and where the nature of the materials is such as to yield readily to these destructive influences, it would be unreasonable to look for vestiges of ancient lumps above that level. Such is the case, as before mentioned, on Northeast Pass and its branches.* But the sandier nature of the mudlump mass on Southwest Pass enables it to resist much longer, so that some of the larger and more elevated islands there seem destined to retain, more or less permanently, their present form. For the same reason, perhaps, the Southwest Pass furnishes the one prominent example of the existence of an active and characteristic mudlump, in the level marsh on the right of the channel, about five miles below the Head of the Passes, and seven above the mouth (light-house); distant 1½ miles from the river bank, and about one mile from the beach of West Bay. Double-headed Bayou, or one of its channels, passes within a few hundred yards of this lump; which is so difficult of access that it has been very rarely visited, though plainly visible from the hurricane deck of passing steamers, from which I have examined it with the telescope.

According to Thomassy,† the pilot Ben. Morgan, who has visited it, describes it as being "a regular truncated cone, 20 to 25 feet high and 300 in circumference, spouting at intervals from its summit masses of clayey and sandy mud, which overflows all around."

From the Pass, it now appears as a slightly irregular, conical hill, which, judging from the extent to which it projects above the highest reeds, is about 18 to 20 feet high at most. On its eastern side there is a second cone about half as high, with a very regular slope not exceeding 30°, while that of the large one is at least 45°. A whitish sheen which extends from the summit of the larger cone toward the smaller one, I interpret as a white salty efflorescence; but on the south slope of the smaller

* Col. Sidell mentions a mudlump cone, 18 feet high, on the north side of the Northeast Pass, in the marsh. It has probably succumbed since his visit, as in passing the spot I was unable to perceive any elevation, nor was it known to the pilots.

† Géol. prat. de la Louisiane. p. 56. I shall designate this cone as "Morgan's Lump."

cone, the glittering of a flowing mudstream was unmistakable. Inasmuch as in Morgan's account of his visit the smaller cone is not mentioned, it is presumable that it has been formed since, by a lateral eruption; the old cone having, perhaps, reached the extreme limit of height to which mudlump force can raise its materials.

The steep slopes of both the old and new cone are suggestive as to the influence of sandiness on that feature, and the explanation of the steep inclination of strata, observed chiefly on Southwest Pass.

It is my impression that another cone exists in the marsh about two miles south of these. It is almost screened from view by the reeds, but the telescope shows it to be distinctly conical. It does not seem to have attracted notice heretofore.

But if mudlump cones are scarce in the marshes, the same is not true with reference to the salt and gas springs, which are reported to be quite abundant by the hunters—the only men whose occupation leads them to "thread the pathless waste" of reedy marsh, otherwise seldom visited, save by surveying parties, and alligators. These springs are found on or around all mudlumps, of whatever age; even on the shoals left behind by disintegrated lumps, where they issue under water, sometimes altering perceptibly the character of the water in the immediate neighborhood. The Southwest lighthouse was originally built on a mudlump separated from the mainland by a bayou; this is now filled up, but salt springs still issue at several points in the marsh near the foot of the tower. It is obvious that the gradual accumulation of deposit is not likely to check lively springs, possessing sufficient head to rise, hydrostatically, above the level of the alluvium; though in many cases they may lose themselves in the sandy strata.

I have not had an opportunity of ascertaining whether or not salt springs are known to exist in the marshes near the Forts, and above. I fully expect to find, however, that they do exist, though, for obvious reasons, they will become less and less abundant as we ascend the river. At New Orleans, as already stated, gas and salt water are reached, and brought to the surface with considerable vehemence, by bores varying from 31 to 56 feet;* and I have no difficulty in believing in the correctness of the impression made upon Col. Sidell, that the foundations of the New Orleans customhouse were located upon a mudlump.† That such obstinate resistance as that of the "Head of the Passes" to denudation can hardly be attributed to a mass of river deposit, I have already intimated. A large mudlump mass has, probably, first caused the deflection.

[To be continued.]

* See above, p. 245.

† Lyell's Principles of Geol., 10th ed., p. 552

Origin of the Mudlumps.—The causes which give rise to the formation of mudlumps have been to some extent discussed by Sidell, Thomassy, and Lyell (*loc. cit.*). The former is inclined to ascribe the upheaval *chiefly* to the pressure of gas formed in the decay of driftwood and the like, buried in the river deposits. Thomassy resorts to the hypothesis of the existence of subterraneous channels communicating with the river, or with equally hypothetical reservoirs of water, far above; while Lyell ascribes the bulging of the bottom to the pressure of newly formed deposits upon a substratum of yielding mud, accompanied, and aided incidentally only, by the evolution of marsh gas in the decay of organic matter. I myself, having become aware of the existence of a strong artesian water pressure in the littoral formations of the Gulf, was inclined to ascribe the origin of the upheaving force to that source; and my visit to the mouths had for its object mainly, the comparison of the facts with each of the three admissible hypotheses, that of Thomassy being too fanciful to be seriously entertained.

As already stated, I at once found that the evolution of gas in the active vents was too insignificant to be considered as the cause of the rising of the liquid mud, which so greatly exceeded it in bulk, that the ascensional force of the bubbles, especially in so wide a vent-tube, would be utterly inadequate to balance the downward tendency of so heavy a liquid. It might still be alleged, in favor of the gas-hypothesis, that its pressure might be exerted statically upon the surface of the mass of liquid mud covered by impervious strata; but it is obvious that in such a case, the gas itself, necessarily accumulating at the highest, and therefore weakest, points, of the superincumbent mass, would be much more likely to break through by itself, promptly exhausting its force and quantity at any one point. No such rushing outbreaks of gas have ever been recorded, save in the case of blowing up of a lump with gunpowder; and, as Lyell remarks, this view renders inexplicable the occurrence of lumps exclusively about the mouths of the passes.

The latter objection applies equally to the hypothesis of the artesian origin of mudlump force, unless upon the (unproved) supposition that the excavation of the river channel might have rendered the outbreak of the artesian water easier there than elsewhere. But instead of *excavating*, the Mississippi has for a long time past always thrown *shallows* in advance of its

mouths; and unless it were conclusively proven that *the matters ejected by the mud-springs* were such as could not originate in the present delta formation, the artesian hypothesis must lose all show of probability. An accurate investigation of the matters in question, solid, liquid, and gaseous, was therefore indicated. A few specimens for this purpose were collected for me by Mr. Marindin, in 1867; but the perusal of his report accompanying them convinced me that a personal examination *in loco* could alone insure a perfect certainty as to their significance, and accordingly, in the autumn of the same year, I re-collected specimens from the same, as well as from other localities. Very unfortunately, the arrangements for gas analysis at my command were so imperfect that, while waiting for their improvement, the gas specimens were so vitiated by diffusion through corks and wax as to render them useless; and I have been unable to replace them as yet, but hope to do so in the near future.

Mudlump Gases.—The examination of the water and mud seemed, however, most likely to conduce to a solution of the problem, at any rate; for after all, the only information which could be furnished by gas analysis would be to indicate, by the greater or less amount of carbonic acid present, whether the gas originated from matter comparatively fresh and in its first stage of decomposition, or had its source in materials far advanced toward the stage of lignite or coals. The only perfectly reliable determination made was that of the carbonic acid contained in the gas collected from the most easterly active cone on Marindin's Lump, Passe à l'Outre, the rest of the determinations being somewhat vitiated, though doubtless very nearly correct.* The result was as follows:

Gas from East Crater, Marindin's Lump, Passe à l'Outre.

Carbonic acid,	9·41
Marsh gas,	86·20
Nitrogen,	4·39
	100·00

Oxygen was not present.

The percentage of carbonic acid in this gas is very unusually large; its composition is nearest to that of the gas from common swamps, where vegetable matter is in its first stages of decay. The proportion between marsh gas and nitrogen is nearly the same as in the gas from the gas wells at New Orleans (see p. 245): but there is three times as much carbonic acid present

* After the explosion in the eudiometer, some nitrate of mercury was observed on its walls, in consequence of inadequate dilution of the gas. But the marsh gas was estimated from the carbonic acid absorbed after the explosion, the nitrogen by difference.

in the mud-lump gas, in accordance with the presumable more advanced stage of decay existing in the former locality.

Mudlump Spring Waters.—In taking specimens, common quart bottles were filled by immersion in the craters themselves, and immediately sealed. The liquid mud thus obtained would, after a while, separate into a lower stratum of pretty solid mud, and an upper one of clear water, in varying proportions. For analysis, the latter was carefully decanted, and the turbid part rapidly filtered through a Bunsen's pressure filter, and measured. 400 ccm. were then boiled to precipitate carbonates and silica, the filtrate re-diluted to the original bulk, and from 50 to 100 ccm. used in the determination, in separate portions, of chlorine, of lime and magnesia, and of sulphuric acid and alkalies, respectively; while a fourth portion served for an approximate determination of the solid residue, for the sake of roughly controlling the final results.*

I give below, in tabular form, the results of these analyses; presented in three different forms, for the sake of ready comparison with the composition of sea-water, from which they seem to be derived by a series of reactions easily understood from the nature and condition of the materials with which they are associated.

I. Water from the basin of a spring on a mudlump off Stake Island, Southwest Pass. Evolves gas and water in about equal proportions, no mud, but only fine sandy matter; and water flows off clear over the rim of the basin, which is two feet above tide level, and at the foot of a large extinct cone with a lagoon, surrounded by a high rim, in the center.

Water about $\frac{1}{4}$ of the bulk in bottle, the rest fine sand. Taste, very salty; color, slightly yellowish; turns brownish turbid very quickly on exposure to air. Coll. Dec. 3, 1867.

II. Water from a mudlump spring on Northeast Pass, collected by H. L. Marindin, of U. S. Coast Survey schr. Varina, in February, 1867.

According to the recollection of one of the crew, this specimen was taken from the same cone as the following one (No. III).

Water clear, faintly yellowish, about $\frac{1}{4}$ by bulk of the contents; the rest sandy mud. Turns turbid rapidly on exposure to air.

* With mixtures of this kind no method but that of evaporation with excess of carbonate of soda will yield anything more than an approximate estimate of the solid residue; involving an amount of labor and care not always justified by the end in view, when the relative amounts of ingredients can serve to control. The chlorine determination being the most accurate, and almost always in excess of the bases found available to form chlorides, the chloride of sodium, as here recorded, is the *calculated* amount, as is also the sum of ingredients.

Analyses of Waters from Mudlump Springs, Mississippi Passes.

	Southwest Pass. I.			Northeast Pass. Salt Spring Island. February. II.			Northeast Pass. Salt Spring Island. December. III.			Passe à l'Outre. Marindin's Lump. East Crater. IV.			Passe à l'Outre. Marindin's Lump. West Crater. V.		
	a.	b.	c.	a.	b.	c.	a.	b.	c.	a.	b.	c.	a.	b.	c.
Chloride of Sodium,	2·5374	80·060	81·662	2·7847	81·937	84·117	2·7751	82·809	84·670	1·2439	79·094	85·857	1·7544	79·708	84·055
" Potassium,	0·0280	0·884	0·901	0·0441	1·297	1·332	0·0441	1·316	1·346				0·0166	0·754	0·795
" Calcium,	0·0725	2·287	2·388	0·0342	1·006	1·033	0·0638	1·903	1·947	0·0018	0·114	0·124	0·0649	2·947	3·109
" Magnesium,	0·4635	14·624	14·917	0·4475	13·168	13·518	0·3945	11·773	12·037	0·1962	12·475	13·543	0·1259	11·440	12·061
Sulphate of Calcium,	0·0007	0·022	0·023							0·0069	0·439	0·476			
" Magnesium,															
Carbonate of Calcium,	0·0011	0.035		0·0313	0·921		0·0001	0·003		0·0695	4·419		0·0230	1·045	
" Magnesium,	0·0446	1.407		0·0447	1·315		0·0724	2·160		0·0392	2·492		0·0745	3·385	
" Iron,	0·0158	0.499		0·0121	0·356					0·0119	0·757		0·0128	0·582	
Silica,	0·0007	0.022					0·0012	0·036		0·0033	0·210		0·0030	0·139	
	3·1643	99·840	99·891	3·3986	100·000	100·000	3·3512	100·000	100·000	1·5727	100·000	100·000	2·2010	0·06100	100·000
Specific Gravity,		1·02388			1·0244						1·01196			1·01689	

a. Ingredients in 100 ccm. of the water. b. Ingredients in 100 parts of solid residue. c. Ingredients in 100 parts of solid residue exclusive of carbonates and silica.

TABLE—continued.

	Knight's Gas Well. New Orleans. VI.			Gulf Water. 30 miles out. VII.		Sea Water. Average composition. VIII.	
	a.	b.	c.	a.	b.	a.	b.
Chloride of sodium,	0·02310	37·880	56·479	1·6723	76·870	2·700	77·032
" potassium,	0·00790	12·950	19·315	0·0357	1·640	0·070	1·997
" calcium,	0·00060	0·980	1·467				
" magnesium,	0·00630	10·330	15·404	0·2310	10·620		10·271
Sulphate of calcium,						0·360	
Bromide of magnesium,				trace.	trace.	0·002	0·058
Sulphate "	0·00300	4·920	7·335	0·1077	4·950	0·140	3·994
				0·1289	5·920	0·230	6·562
Carbonate of calcium,	0·01120	18·360				0·003	0·086
" magnesium,	0·00760	12 450					
" iron,							
Silica,	0·00130	2·130					
	0·06100	100·000	100·000	2·1756	100·000	3·505	100·000
Specific gravity,				1·01630		1·0298	

III. Water from faintly active cone on Salt Spring Island, off Northeast Pass; from crater on west side of island, about ten feet above sea-level. Collected Dec. 2, 1867.

Water very salty, about $\frac{3}{4}$ of the whole mass; the rest, a somewhat sandy mud; color, slightly yellowish; turns turbid rapidly on exposure to air.

The larger proportion of water in this specimen, as compared with the preceding, doubtless results from the comparative inactivity of the cone, as compared to that at the time of high water in February. The same fact may account for some of the difference in composition.

IV. Water from East Crater on Marindin's Lump, Passe à l'Outre. See p. 362. Collected Dec. 2, 1867.

Forms about $\frac{3}{5}$ of the bulk in the bottle, the rest is soft clayey mud. Faintly brownish, clear; becomes brownish turbid rapidly on exposure to air.

V. Water from West Crater on Marindin's Lump, Passe à l'Outre; same date.

Water about $\frac{1}{4}$ of bulk in bottle, the rest clayey mud. Not very salty; colorless, but turns turbid quickly on exposure to air.

VI. Water from gas well bored by J. B. Knight, at New Orleans. Clear, with a little sand at bottom; taste, faintly brackish.

VII. Water of the Gulf of Mexico, taken from surface 30 miles out, southeast from Southwest Pass, Dec. 1867.

VIII. Average composition of sea-water, according to Regnault.

The general results deducible from the above analyses may be thus stated:

1. There is a general similarity of composition between the waters of the mudlump springs, indicating their derivation from a common source of supply. But springs on the same lump, as well as the same spring at different times or stages of water, may vary quite sensibly, both in composition and concentration. Their density is generally inferior to that of sea-water, though at times approaching it closely.

2. There is an obvious approximation of the ratio between the two chief bases—sodium and magnesium—to that existing in sea-water; the variations being no greater than are observed in sea-water from different localities.

3. The most obvious difference is the absence of sulphates, and their partial replacement by chlorides: also

4. The presence of large amounts of the carbonates of the earths, as well as of iron, dissolved in carbonic acid.

5. The amount of potassium salts is decidedly diminished.

6. Bromids appear to be entirely absent, and are present in traces only, in the water of the Gulf itself.

It is stated that the waters of some of the springs are fresh. I have found all brackish *at least*, and as the population of the delta is much in the habit of drinking water of questionable freshness, their judgment in the matter may not be the most reliable.

As regards the water of the New Orleans well, though at first sight it differs materially from the others, it will be observed that when in C, potassium and sodium chlorides are classed together, its composition becomes not unlike the mudlump waters. Its great dilution accounts for the excessive proportion of carbonates.

The Gulf water approaches very closely in its composition to the normal one of sea-water, as given by Regnault.

Mud from Mudlump Springs.—I have already stated, that the stratified material of the mudlumps (whether formed by the action of mud springs, or bodily upheaved) is free from visible shells or other fossils, save particles of woody matter; while the amorphous material which forms the surface and generally also the beach, often abounds in such organic remains as are now usually washed ashore, having manifestly been *cast* up and imbedded in the mud by the waves.

I have examined microscopically the mud remaining in the specimen bottles after decanting the water for analysis; they were immediately refilled with distilled water, and kept closely stopped until examined. I give below the record of examination of the mud, corresponding to analysis No. V, from West Crater on Marindin's Lump. Two or three others similarly examined gave a like result.

A sample from the general mass shows it to consist mainly of very fine quartz sand, mostly angular, with but a few large, angular grains; and but little true clay.

In washing the mass, even the first washings were found to contain but little clay, but chiefly very fine suspended silex. A few ill defined spicules, a Navicula, and bark fibers.

In the middle portion, spicules a little more abundant.

In the coarsest portion, much variously colored mica, along with, mostly sharply angular, quartz grains; numerous particles of water-browned wood; very distinct spine of a radiate; several specimens of Rotalina, and fragments of same as well as Uvigerina, Cristellaria, Amphistegina, and Coccineis? Also iridescent fragments, showing lines of growth, from the edges of larger bivalves.

Quartz grains mostly transparent and angular; some of milky, oil-green, and rose quartz; these mostly rounded. This sand resembles closely that of the bottom outside Northeast Pass bar, in 40 to 50 feet water; specimens of which were furnished me by the Coast Survey party, under command of Capt. F. V. Webber of the schooner Varina, in 1869.

Specimens from mudlumps on Southwest Pass show coarser sand, and rather more Foraminifera.

The character of the materials ejected by the mudlump springs, as determined by the foregoing investigations, may be summed up as follows:

1. The *gas* is such as is evolved by vegetable matter in its *first* stages of decay or lignitization.

2. The *earthy matter* contains both river and marine fossils—driftwood reduced almost to its cell-elements by maceration and trituration, as well as Foraminifera. Its fineness is such that, before final deposition, it may have been carried out into water of considerable depth.

3. The mudlump waters appear to be sea-water more or less diluted, and chemically changed under the joint influence of fermenting organic matter, and the more active ingredients of the river deposit, viz: carbonates of lime and magnesia, and oxide of iron.

The first effect thus produced would probably be the addition of the soluble carbonates of these metals to the solution. But the soluble sulphates could not, in the presence of a soluble iron salt, long resist the reducing influence of decaying organic matter. As usual under such circumstances,* iron pyrites would be formed, withdrawing in the end all the sulphuric acid from the solution, and forming, instead, equivalent amounts of the respective carbonates. The amounts of the chlorides of

* See Bischoff, Chemische Geologie, vol. i, p. 559.

sodium and magnesium originally present would thus, also, be relatively increased; and this again tallies with the analytical results. Yet while the proportion between these bases is maintained* the actual *replacement* of sulphate of magnesium by the chloride constitutes a change not readily explained. At first sight it would seem that the excess of chlorine belonging to the chlorides of calcium and magnesium must be an outside accession; but our knowledge of the mutual reactions between the substances here present under strong pressure, is perhaps too fragmentary to justify an assertion on this point.

The diminution of the potash salts is doubtless referable to their absorption by the clays present, in preference to all other compounds. The filtration of sea-water through soil would, according to Liebig's experiments, produce a like result.

Conclusions.—In view of the foregoing facts, the explanation of mudlump phenomena suggested, substantially, by Sir Chas. Lyell, seems the only tenable one; it requires, however, some modification as regards the mass supposed to exert the pressure, and some corollaries as to the mode of action.

I have before suggested, that the rapid protrusion of the mouths of the river into the Gulf, in advance of the body of the delta, is owing to the shelf of "blue clay bottom" extending, at a comparatively slight depth below the sea-level, and with a gentle slope, far out into the Gulf. It is upon this impervious clay that the present bars are based; and upon it, in advance of the bar, will be deposited the finest of the river mud, at a depth at which, perhaps, the sea-water is at the time quite undiluted, and fully adapted to marine life; which will therefore deposit its vestiges in it, associated with the finest particles of driftwood, etc. Mud thus deposited may remain unconsolidated for a great length of time, unless the water be drained off or through it by some means.

The bar, in its annual advance of about 338 feet, will cover over this liquid mud stratum, exerting a pressure much greater than that of the sea; and were it resting on a pervious bottom, the liquid mud would doubtless soon be consolidated into a sheet of clay. As it is, the tendency will be to squeeze it from under the crest of the bar, both seaward and landward. The very gradual seaward slope of the bar will render the movement in that direction a very slow one, under a greater depth of water and heavy frictional resistence. Not so on the land side, where, as the bar advances, the superincumbent pressure is measurably relieved by the erosion of a channel by the

* The ratio is for

Atlantic sea-water,	30·5 : 3·0	Marindin's Lump water,	30·5 : 2·8 (min.)
German Ocean water,	30·5 : 4·0	Southwest Mudlump,	30·5 : 3·56 (max.)
Average sea "	30·5 : 3·4	Average of those analyzed,	30·5 : 3·1

current, which, especially in flood time, carries much of the bottom deposit bodily over the bar and drops it to seaward.* At weak points of the bottom inside the bar, therefore, the upward pressure of the mud may cause a bulging up at least to the level of the bar-crest, and, perhaps, taking into account the difference in the specific gravities of the comparatively solid bar and liquid mud, even as far as the surface of the water. But this, considering the question as coming within the domain of liquid statics, would seem to be about the extreme limit to which the bottom itself could be brought up.

I have found the specific gravity of the mud flowing from the West Crater on Marindin's Lump, to be about 1·25; that from the cone on Salt Spring Island, on Northeast Pass, 1·30; while that of bar deposit from the crest of the Northeast bar, wet as brought up by the lead, was 1·75. The heights of communicating columns of these substances, if sensibly liquid, should be as 5 to 7; but this ratio could apply, in the case of upheaval, only so far as the *difference* of level between the bar and the upheaved bottom is concerned, since the latter must be presumed to be similar to the bar in its materials and structure. Should the current, however, continue to denude the crest of the upheaved mass, the rising would continue and the semi-fluid mud might finally break through, forming a mudspring, the height of whose vent above its source might finally increase to the extent corresponding to the difference of specific gravity.

The craters of mudlumps have been sounded to the depth of 24 feet, but no precautions were used to insure reaching the actual maximum depth. In the borings made for the foundation of a lighthouse on the Southwest Pass, by Mr. A. Palms (the record of which was courteously forwarded to me by the Engineer Dept.), a stratum so soft that the augur sank in it by its own weight, was met with at 58 ft., after striking, at 56 ft. a stream of water which "filled the pipe."

If then, the mud stratum, lying, say 60 ft., below the surface, be pressed by a column of deposit of 1·75 sp. gr., mud of sp. gr. 1·25 could thereby be raised 24 feet above the top of the pressing column; and this, considering the average depth of water on the bar, would account for the greatest heights to which cones are built up off the mouths.

But this is a close calculation, even if the data upon which it is based be deemed admissible in the form I have given them; and the frequency and energy with which the upheaving force acts, coupled with the fact that when a mudlump rises in the channel, so far from suffering denudation to the extent required for the breaking through of the mud, it more generally causes a silting up of the channel: seems to me to indicate that

* Humphreys and Abbot's Rept., p. 446.

a stronger force, less delicately balanced than the equilibrium of the bar, is "at the bottom" of the whole phenomenon.

This force, I think, is to be sought in the constantly increasing weight of the alluvial area above the mouths, which, itself possessing a series of mudlump vents at one time, must yet be resting in a great measure upon the still unexhausted mud stratum; as is proven by the existence of active lumps in the marshes, even though the increased resistance of superincumbent deposit as well as matted vegetation must render their occurrence there a rarity. There must still be a communication of liquid pressure between the older and newer portions of the modern delta; and this point is especially strengthened by the fact that a high stage of water in the river, which does not sensibly affect the depth on the bars, yet exerts a decided influence on mudlump activity. The river not only overflows the marshes, but loads them with additional sediment; and doubtless the increased hydrostatic pressure stops many a vent of gas, mud or water, which ordinarily discharges into the river's bed.*

Morgan's Lump, in the marsh of Southwest Pass, and Marindin's Lump on Passe à l'Outre, are now known to have been in undiminished activity for twenty-five years at least. Since that time the bars have moved gulfward a mile and a half; and one would think that, if the activity of the cones depended upon them alone, a notable difference ought to have been observed. But if the main force is a *vis à tergo*, while the bar serves mainly to prevent the escape of the mud to seaward, there is good cause for the secular persistence of vents that have escaped mechanical obstruction.

How far above the present mouths the head of pressure may extend, I do not pretend to conjecture. The borings at New Orleans seem to indicate that the mud stratum originally existed there also, but it would be extravagant to suppose that such pressure as that exerted in the gas wells of that city, could now be felt a hundred miles below. Yet it seems not at all unlikely, that the weight which steadily forces up the liquid mud to the top of Morgan's Lump, seven miles above the mouth, may, in part, be furnished by the enormous mass of vegetation which annually develops in the marshes, willow battures, and perhaps even cypress swamps above. Nor is the effect of gaseous pressure resulting from the constantly pro gressing decay of organic matter to be overlooked, although I doubt that this cause plays, ordinarily, anything more than a very subordinate part.

* I give on the plate (page 358) an ideal section, illustrating this explanation of the "origin of mudlumps."

Future observations, systematically carried out, will doubtless solve a good many of the questions here mooted; and though they may not lead to the suggestion of any means whereby the "evil geniuses of the Passes" may at present be conjured, a more precise knowledge of data, as well as of the statics and dynamics of *mud*, may enable us to predict at what point of advance of the mouths into the deeper water of the Gulf, their formation must cease. The Southwest Pass appears to be nearest that consummation devoutly to be wished; and were the closing of the other outlets practicable, the advance of the Southwest bar might become so rapid, as to let the youngest of the living generation witness a diminution of mudlump upheaval. Ultimately, the mouth might thus become similar to those of the Orinoco and Amazon; but until then, ceaseless activity of the river in the formation of bars and mudlumps must, in the interest of navigation and commerce, be met by an equally ceaseless and diligent effort for their removal from the channel. For while a concentration of the river current might possibly be made to maintain the needful depth upon the bars, its utmost erosive energy will be powerless against the tough, inert masses of the mudlumps.